JUNE 1961
VOLUME 1, NUMBER 6

Materials Research & Standards

Bulletin of AMERICAN SOCIETY FOR TESTING MATERIALS

Materials
Research & Standards

Vol. 1, No. 6, June 1961

Published as ASTM BULLETIN from 1921 through 1960.

Telephone: LOcust 3-5315 **Cable Address: Testing Philadelphia**

TECHNICAL PAPERS

ARTICLES

DEPARTMENTS

17,750 copies of this issue printed.

Materials Research & Standards is indexed regularly by Engineering Index, Inc., and is available on microfilm from University Microfilms, Ann Arbor, Mich.

Materials Research & Standards is published monthly by the American Society for Testing Materials. Publication office at 20th and Northampton Sts., Easton, Pa. Editorial and advertising offices at the Headquarters of the Society, 1916 Race St., Philadelphia 3, Pa. Subscriptions: United States and possessions, one year, $5.00, two years, $8.50, three years, $12.00; Canada, one year, $5.75, two years, $10.00, three years, $14.25; elsewhere, one year, $6.50, two years, $11.50, three years, $16.50. Single copies, 75 cents. Second-class mail privileges authorized at Easton, Pa.

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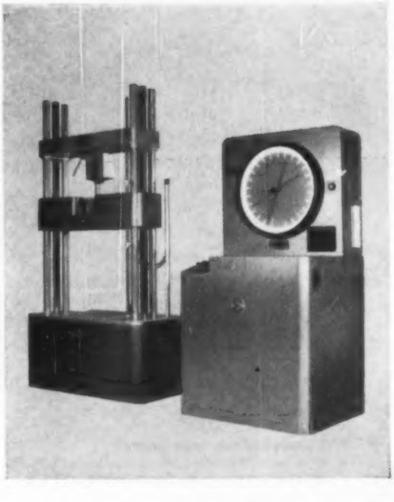

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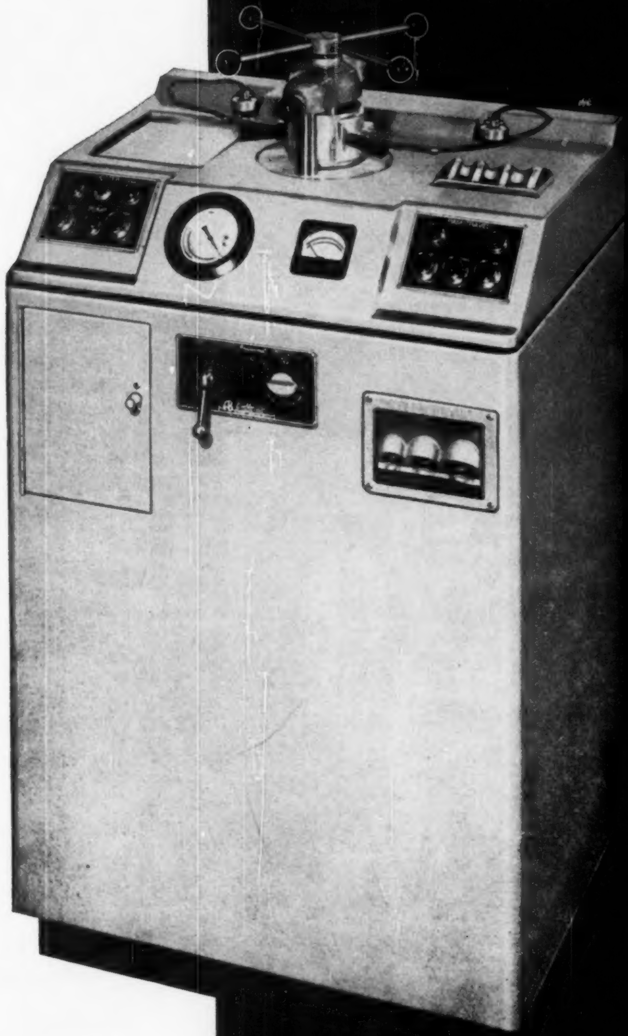

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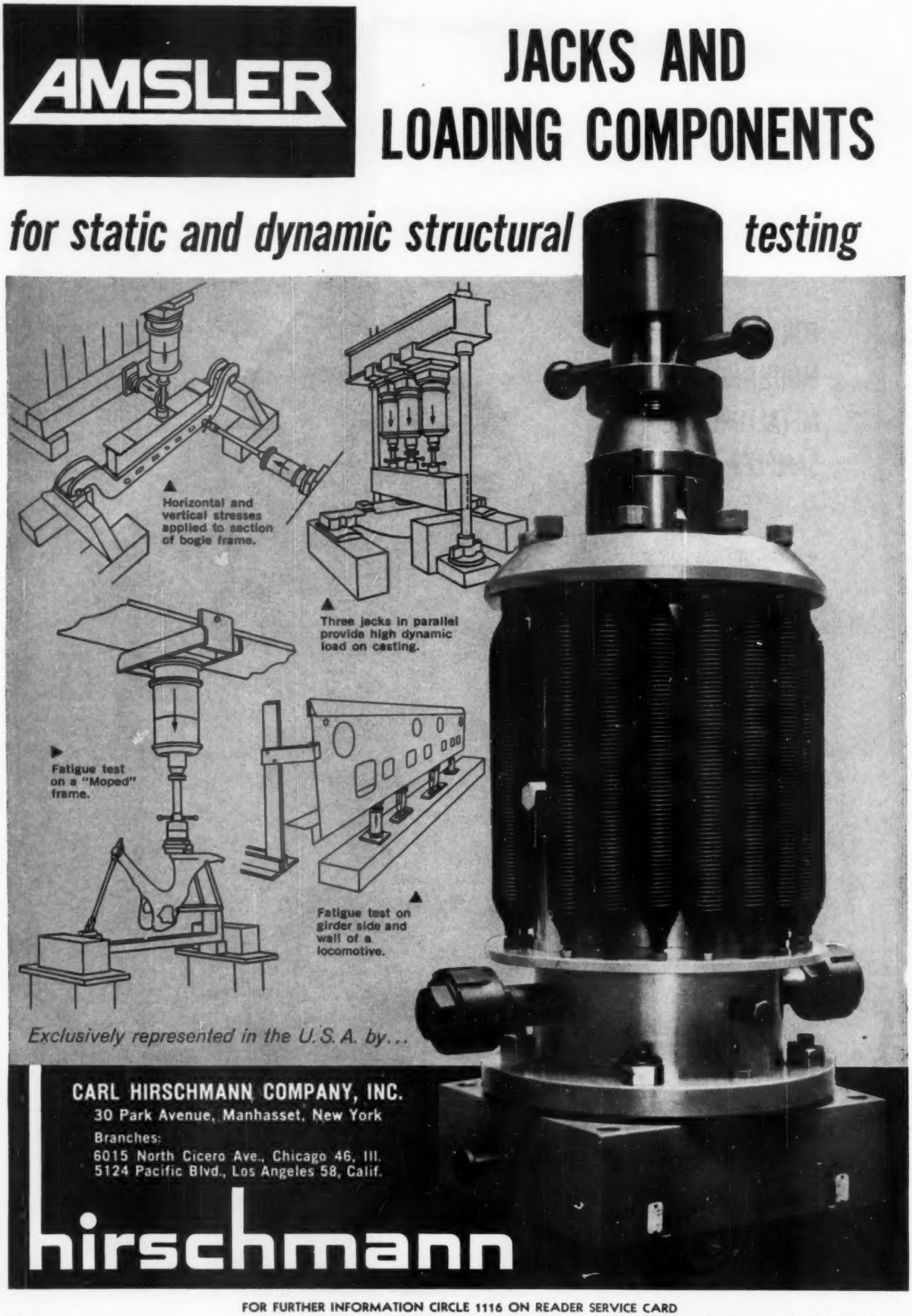

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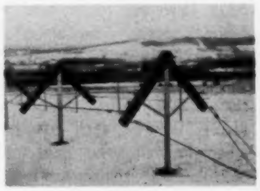
In This Issue...

COVER PHOTO:

Seven-wire strand specimens exposed at the New York State College of Agriculture, Cornell University, Ithaca, N. Y., on November 12, 1936. These were among some 10,000 specimens of plain and fabricated wire exposed at eleven test sites from coast to coast by Committee A-5 on Corrosion of Iron and Steel. A 20-year progress report is reviewed on p. 484.



Materials Research & Standards

Volume 1, Number 6, June, 1961

Needed: More Talk Less Communication[1]

SCIENCE—both the pure and the not so pure—is a vast book in which man writes all that he learns of the world that he can touch, see, hear, smell, or taste. At this hour in the life of Man, when he can hang in space to see the earth, and at the next stroke may touch the moon, those who write in this book must strive to use words that strike the minds of all men. For it may have come to this: to see is to live; to be blind is to die.

This is not to say that man will be saved by science. It *is* to say that each man must learn the lore of science, he must learn the thoughts of those who work in science, he must learn to put the fruits of science to their best use. But if he is to learn these things, the men of science must learn to speak to him in his own tongue.

There is no law, so far as we know, that says a man must use short words when he talks and long ones when he writes. Nor is there a rule to force us to seek out the big word when our thoughts run deep. In fact, when the urge to tell burns in us, we turn to the short word. When we swear, we slash and bruise with the sharp, curt word. When we pray, our souls soar on wings of light, brief words. When we love, the sweet, spare words pierce straight to the heart. When we urge or drive, the words are pruned and clipped, they dart to the mind in one clean stroke. The long words bounce off the shell, weight us to the ground, probe in vain for the path to the heart or to the mind.

Each man who takes his pen in hand to tell his peers what he has thought or done should make this pledge: "I swear that what I write will speak to men in words that they can seize and hold. I will shun the blunt, stiff, thick words that clot the brain and turn clear minds to sour ooze. I will cleave to the keen, terse, brisk words that bear true to the mark and shed a pure gleam in the dark. My one aim will be to see that those who scan my words can read my thought."

Quiz: Which word in this piece (save the last one) has more than one syllable?

A.Q.M.

[1] With thanks for the idea to Joseph A. Ecclesine's "**Big** Words Are for the Birds," in *Printers' Ink*, Feb. 17, 1961.

Hardness-Tensile Strength Conversion for Rockwell Hardness, C Scale[1]

Originally the ASTM-SAE hardness-tensile strength curve differed from the QQ-M-151a curve above the 200,000-psi tensile strength level (Rockwell hardness C 43), but when the Federal Test Method Standard No. 151 was published in July, 1956, the hardness-tensile strength curve was revised to agree with the ASTM-SAE curve in the interest of uniformity. Recent increases in strength levels in use in aircraft components requiring inspection by hardness testing have resulted in difficulties due to the fact that these recent conversions seemed to show that for a given Rockwell hardness, C scale, the tensile strengths as shown on the ASTM-SAE curve were on the low side by as much as 14,000 psi. Accordingly, Subcommittee 6 on Indentation Hardness of Committee E-1 on Methods of Testing set up a task group with W. H. Mayo of U. S. Steel Corp. as chairman. This task group was composed of members of ASTM, SAE, government, and industry to resolve the hardness-tensile strength relationship of steel heat treated above Rockwell hardness C 40.

The task group agreed that the work should be undertaken under the following conditions:

1. Confine the original study to SAE 4340 steel.
2. At least five installations should participate in the test program.
3. The Wilson Mechanical Instrument Div., American Chain and Cable Co., Inc., would furnish standard blocks and would conduct check hardness tests on the broken tension specimen ends.
4. U. S. Steel Corp. would furnish the steel.
5. Bethlehem Steel Co. would handle the heat treatment.
6. Watertown Arsenal would machine test specimens.
7. A special committee would draw up specific procedures to be followed.

The following members were appointed to this special committee: D. E. Driscoll, Watertown Arsenal, Chairman; H. L. Fry, Bethlehem Steel Co.; V. E. Lysaght, Wilson Mechanical Instrument Div., American Chain and Cable Co., Inc.; and J. L. Beaton, Bendix Products Div.

At the first meeting of the above committee it was decided that the following ten installations would participate in the test program: National Bureau of Standards, U. S. Steel Corp., Bendix Products Div., Menasco Manufacturing Co., Bethlehem Steel Co., Wright Aeronautical Corp., Republic Steel Corp., Frankford Arsenal, Watertown Arsenal, and Carpenter Steel Co.

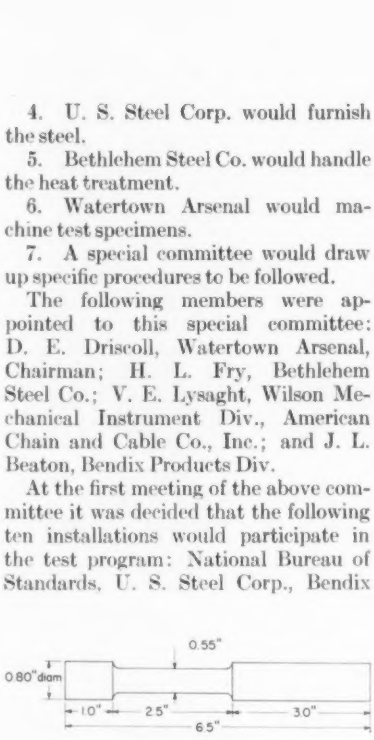


Fig. 1.—Specimen dimensions.

TABLE I.—CHEMICAL COMPOSITION OF HEAT NO. X 38314.

Element	Per Cent
Carbon	0.42
Manganese	0.78
Phosphorus	0.014
Sulfur	0.012
Silicon	0.29
Nickel	1.84
Chromium	0.78
Molybdenum	0.26

TABLE II.—JOMINY HARDENABILITY TEST DATA.

Normalized 1600 F, quenched 1550 F.

Distance from Quenched End, in.	Rockwell Hardness, C Scale
1/16 to 4/16	60
5/16 to 7/16	59
8/16 to 19/16	58
20/16 to 32/16	57

Test Program

The program officially started when Watertown Arsenal received from the U. S. Steel Corp. ten sections, each 10 ft long and $1\frac{1}{4}$in. in diam, totaling 440 lb of a 4340 steel obtained from a regular electric furnace heat and made with a normal two-slag process and poured into 24 by 24 in. hot top molds. The heat number, composition, and Jominy hardenability were as shown in Tables I and II.

Machining

Watertown Arsenal cut these steel bars into $6\frac{1}{4}$-in. long sections (mixed up and numbered at random from A1 to A110). All blanks were normalized at 1625 F for $1\frac{1}{2}$ hr and air cooled, then annealed at 1250 F for 2 hr and air cooled. After heat treatment, the blanks were rough-machined as shown in Fig. 1. The additional 2 in. at one end were left for hardness checks after the final heat treatment. These blanks would later be divided in five groups of 22 each for heat treatment to the following hardness levels on the Rockwell C scale: 43, 47, 50, 53, and 55.

Heat Treatment

The 110 blanks were then forwarded to the Bethlehem Steel Co., where all of the blanks were quenched in oil from 1500 F and tempered immediately at 250 F for 2 hr. Then 1-in. long pieces were cut from the excess portion of 10 of the blanks, tempered at a series of temperatures, and checked for hardness in order to find the temperatures required to produce the five desired hardness levels. The blanks were then divided into five batches of 22, and one

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[1] Report of a task group of Subcommittee 6 on Indentation Hardness of Committee E-1 on Methods of Testing.

batch was tempered at each of the five selected temperatures.

In the quenching operation four specimens were put into the furnace at a time. Thus the quenching was done in 27 batches of 4 and one batch of 2 bars. Selection of the specimens going into each batch was at random.

The bars were put into the furnace at temperature and held 45 min. It was not practical to stand them on end in the furnace; therefore they were leaned in a nearly vertical position against a steel block which had previously been placed in the furnace and brought up to temperature.

Before they were put into the furnace a wire was attached to each blank for handling in the quench. This wire was wrapped around the gage section near the small end so that the blank was suspended vertically with the large end down. All heating for quenching was done in the same furnace, a Hoskins electric, semimuffle-type furnace.

The blanks were removed for quenching one at a time. However, this was done by two operators so that all four blanks were removed and placed in the quench within a period of 1 or 2 min.

Quenching was done in a fixture consisting of a 10-in. diam vertical pipe. Oil was pumped in at the bottom at a rate of 60 gal per min and allowed to flow out at the open top end. The blanks were suspended in the pipe by means of the attached wires. No agitation other than the flow of the oil through the pipe was attempted.

The oil used for quenching was Atlantic Topaze B, viscosity 105, at 100 F. The temperature of the oil was recorded at the time each batch was quenched.

Each blank was held in the oil quench for 5 min. As soon as all four blanks were quenched they were placed together in a tempering furnace at 250 F. They were held in this furnace for 2 hr and then air cooled.

All tempering was done in the same furnace, a Leeds & Northrup Homo circulating air furnace. Since the quenching batches followed each other at intervals of a little more than 1 hr there were never more than two batches of 4 blanks in the furnace at the same time. The subsequent tempering at higher temperatures was done in another furnace of the same type.

All treatment was done on the day shift so that it could be carefully supervised. From 4 to 7 batches a day were quenched. At the beginning of each day's operation the pyrometers of both quenching and tempering furnaces were checked and new thermocouples were installed.

Five blanks from the first two quenching batches were used to check the hardness after the 250 F temper. For this purpose a piece 1 in. long was cut from the large end of each blank. Rockwell hardness was determined on the cross-section on the end opposite the original end of the blank.

Then these 5 specimens and 5 additional similar specimens taken at random from blanks from other quenching batches were tempered at various temperatures up to 850 F, each specimen at a different temperature.

From the information thus obtained, the following tempering temperatures were selected to aim for the 5 hardness levels:

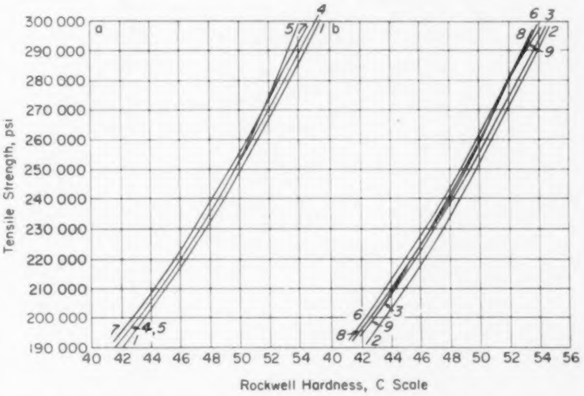
Rockwell Hardness, C Scale	Temperature, deg Fahr
55	375
53	450
50	575
47	700
43	875

Using these selected temperatures, all of the blanks were then tempered in 5 batches of 22 each, one batch at each temperature. Division of the blanks into batches was done at random. All the blanks in a batch were put into the furnace at the same time with the furnace at temperature. They were held for 4 hr and air cooled.

Preparation of Disks

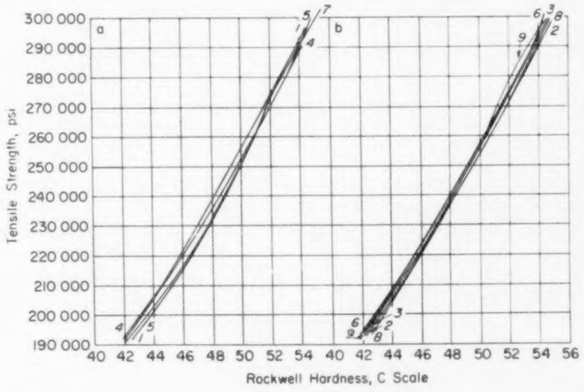
After the final tempering, the extra 2-in. length, or the remainder of it, was cut from each blank. From this a $\frac{1}{2}$-in. thick disk was cut from the inner end. Cutting was done with a soft abrasive wheel using a large volume of coolant.

Both faces of the disk were ground smooth and parallel. Several disks were then etched lightly in cold 10 per cent nitric acid to make sure no tempering or burning occurred in cutting or grinding.



(*a*) For laboratories 1, 4, 5, and 7. (*b*) For laboratories 2, 3, 6, 8, and 9.

Fig. 2.—Uncorrected hardness-tensile strength curves.



(*a*) For laboratories 1, 4, 5, and 7. (*b*) For laboratories 2, 3, 6, 8, and 9.

Fig. 3.—Corrected hardness-tensile strength curves.

TABLE III.—RESULTS OF HARDNESS TESTS ON DISK SPECIMENS.

NOTE.—Results shown cover the 100 specimens actually used in the test program.

Tempering Temperature, deg Fahr	Rockwell Hardness, C Scale		Brinell Hardness	
	Spread	Average	Spread	Average
875	41.9 to 42.5	42.1	370 to 393	381
700	47.0 to 47.7	47.4	441 to 471	447
575	49.7 to 50.2	50.0	474 to 495	481
450	52.0 to 52.7	52.4	507 to 538	517
375	53.9 to 54.7	54.5	522 to 555	544

Hardness Tests

Rockwell hardness tests (see Table III) were made on the face of the disk that was originally adjacent to the end of the tension bar. A Brinell hardness test was made on the opposite face.

Ten Rockwell impressions were made on each disk. The result of the first impression was not recorded. The next five impressions were spaced along one diameter. The last four were along a diameter at right angles to the first.

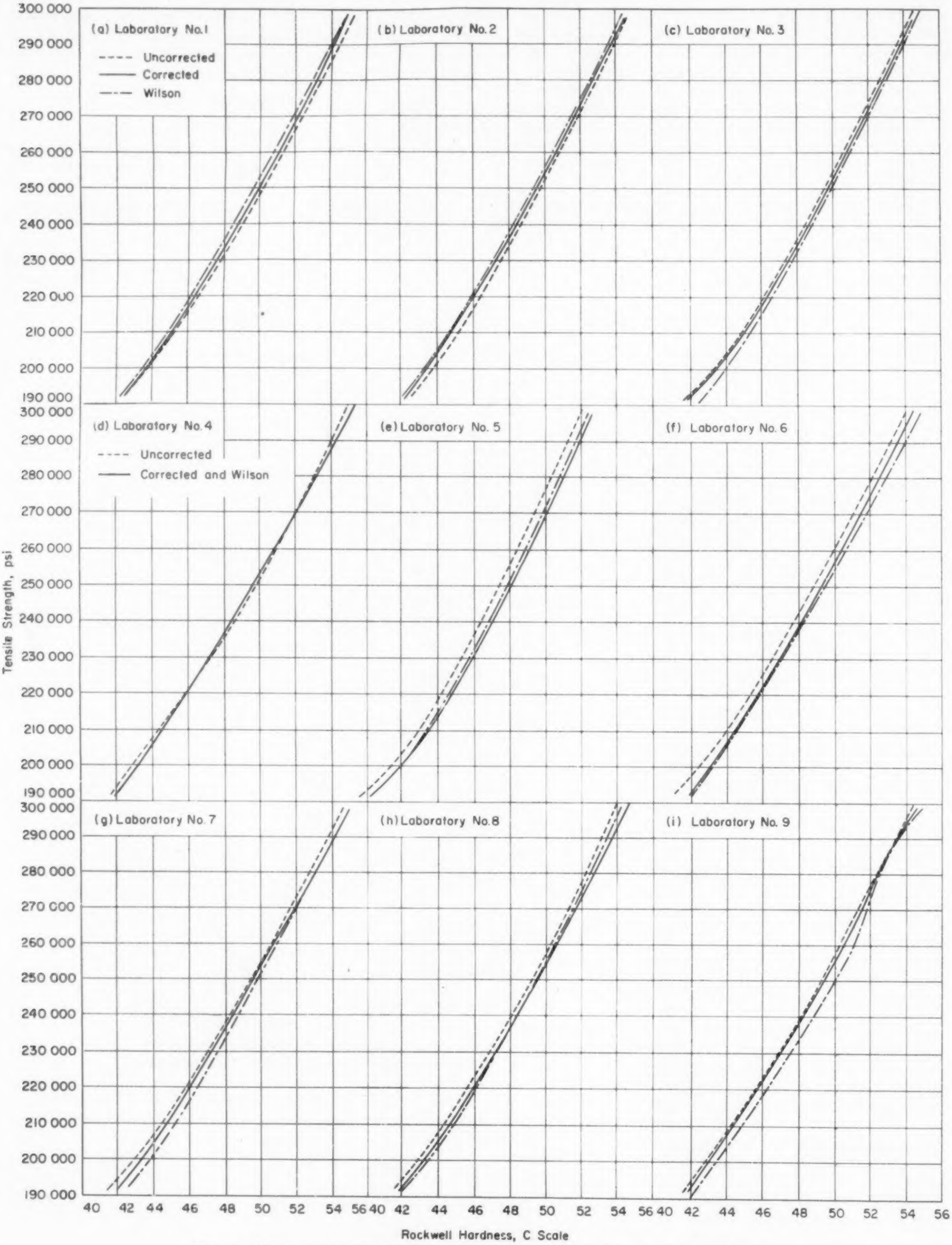


Fig. 4.—Hardness-tensile strength curves for the nine participating laboratories.

Testing was done on a Model 4-YR Wilson Rockwell Tester. This is a motorized machine, chosen because it was felt that the motorized removal of the major load would be more uniform than manual operation. It did not have the automatic zero-setting feature found on some motorized machines. The dashpot of the machine was adjusted so that with no specimen in the machine and a 100-kg load the weight lever dropped to its lowest position in 4.2 to 4.4 sec after the starting button was pushed.

The machine was checked at the start of each testing session using the special check blocks furnished for this project by Mr. V. E. Lysaght. There were six testing sessions, two for the batch of specimens tempered at 875 F and one for each of the other four batches. At each testing session, the machine was checked with all five blocks, regardless of the hardness level being tested at that session.

For each check on each standard block, six impressions were made. The reading on the first was not recorded. Then one impression was made in each quadrant of the block and the last one near the center.

All Rockwell testing and machine checking was done with a spot anvil $\frac{1}{4}$ in. in diam. All readings were estimated to the nearest tenth of a division. The operator was instructed to stop testing at the time of any noticeable vibration, such as from a passing train. All testing was by the same operator.

Brinell hardness (see Table III) on each specimen was determined by means of a single impression on each disk. This impression was made in the center of the face opposite the face used for Rockwell testing. A Riehle Brinell testing machine was used. This is a manually operated hydraulic loading machine with a floating dead weight release at the specified load. A 3000-kg load was used and a 10-mm tungsten carbide ball. Accuracy of the load was assured within 1 per cent by checking with a proving ring. The diameter of the ball was checked periodically during testing to make sure it remained within tolerance on dimensions. For each impression the load was held 15 sec.

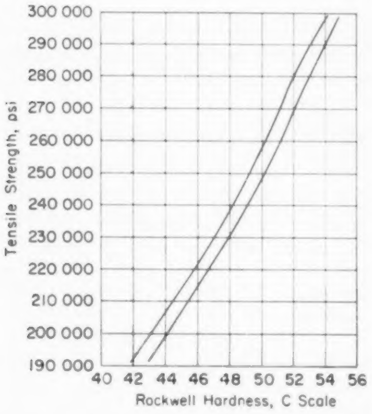


Fig. 5.—Envelope of hardness-tensile strength curves obtained using Wilson Mechanical Instrument Div. hardness readings for all specimens.

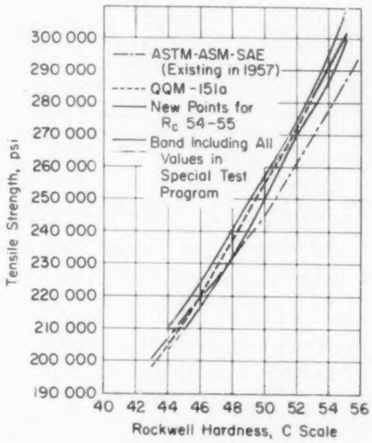


Fig. 6.—Comparison of test results with QQ-M-151a curve.

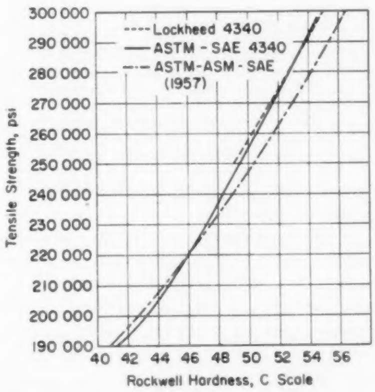


Fig. 7.—Comparison of test curves for three steels.

Distribution to Participating Laboratories

The blanks were then returned to Watertown Arsenal where the gage section was finish-ground to 0.505 ± 0.001 in. at the center of the gage length and tapered 0.005 in. to the end of the gage length. The threaded ends were also finish-ground. When completed, the specimens were sent to W. H. Mayo at the United States Steel Corp., who then forwarded 10 specimens (2 at each hardness level), with duplicate copies of data sheets and instructions, to each of the ten participating laboratories.

Upon completion of tests, each participant forwarded the results and the broken specimens to Mr. V. E. Lysaght for Rockwell hardness, C scale check tests. The second copy was retained by the participant for future reference.

Results and Recommendations

Results of the tests were received from nine of the participants and were plotted by the committee (Figs. 2 to 7). They were then presented to the Joint ASTM-SAE Task Group on Rockwell C Hardness-Tensile Strength Conversion. As the results obtained were almost identical with the original QQ-M-151a curve, the ASTM-SAE Task Group recommended as follows: "Adopt QQM-151a (Amendment 482751) curve with the additional Rockwell "QC" hardness-tensile values for R_c54 and 55." An editorial change was added as follows to remove an obvious error in the old QQ-M-151a curve: "Change the tensile strength value corresponding to R_c 47 from 231,000 to 229,000 psi to smooth out the curve." The additional part of the table with revisions is shown in Table IV.

TABLE IV.—REVISION OF TABLE OF HARDNESS AND TENSILE STRENGTH VALUES.

Rockwell Hardness, C Scale	Tensile Strength, psi
55	301 000
54	292 000
53	283 000
52	272 000
51	264 000
50	256 000
49	246 000
48	237 000
47	229 000
46	221 000
45	215 000
44	208 000
43	201 000

This recommendation was accepted by Subcommittee 6 of Committee E-1 at the ASTM Spring meeting in Chicago, Feb. 1–5, 1960.

Respectfully submitted on behalf of the task group.

David E. Driscoll, *Chairman*
Chief, Materials Testing Laboratory
Watertown Arsenal

James L. Beaton
Materials Engineer
Bendix Products Div.
Bendix Aviation Corp.

H. L. Fry
Foreman, Special Tests
Bethlehem Steel Co.

Vincent E. Lysaght
Sales Manager
Wilson Mechanical Instrument Div.
American Chain and Cable Co.

Modern Concepts in Control of Concrete*

By JOSEPH J. WADDELL

DURING THE past few years there has been much discussion about quality control of concrete. The intent here is not to go over old ground, but rather to attempt to present some new ideas in this respect.

For example, let us consider the precautions that are necessary to ensure a long and useful life for a structure. These precautions are implemented by proper attention to five fundamentals: Investigation of the site, design of the structure, selection of the materials and mix, workmanship in handling the materials and concrete, and maintenance of the structure throughout its life.

Investigation of the site.—Three things are involved in site investigation: Investigation of the fitness of the location, including economic considerations, to suit the requirements of the structure; investigation of the competence of the foundation to carry the expected loads safely, both during construction and afterwards; and investigation of the existence of forces or substances that may attack the concrete. Location and foundation studies are familiar to all engineers; a study to determine the presence of deteriorating agencies may be a new idea to some. Yet such an investigation must be made if the structure is to perform its intended function adequately.

Structural design.—It is obivous that design must be adequate, accomplished by qualified engineers. Not much can be done for a structure that has failed because of poor design. Design should include a consideration of the capabilities of men and machines, to the end that form work and other construction procedures are facilitated.

Selection of the materials and mix.—Data from concrete structures in the vicinity of the proposed construction is of value in determining the suitability of materials, and tests should be made to determine the presence of unsatisfactory or contaminating substances in the proposed materials.

TABLE I.—ELEMENTS OF QUALITY CONTROL OF CONSTRUCTION MATERIALS.

A. PRELIMINARY INVESTIGATIONS

1. Preparation of specifications.
2. Adaptation of standard methods of testing.
3. Establishment of standards for acceptance and control.
4. Development of special test procedures.
5. Investigation, evaluation, and establishment of sources of supply.
6. Arrangement for both off-site and on-site inspection.
7. Preparation of manuals.

B. CONSTRUCTION INSPECTION AND CONTROL

1. Study of service records of materials or combinations of materials.
2. Inspection and testing of materials.
3. Evaluation of test results and determination of suitability of materials.
4. Decision relative to disposition of borderline materials.
5. Control of materials made at the site, such as concrete and bituminous mixtures.
6. Training of testing and control personnel.
7. Supervision of testing and control personnel.
8. Reports.
9. Statistical analysis of data.

C. SOLUTION OF SPECIAL PROBLEMS

1. Trouble shooting for architects and engineers, producers, or manufacturers.
2. Consultation on special problems concerning construction materials.
3. Research and development of new methods and equipment.

Workmanship in handling the materials and concrete.—This includes preparation of the materials, batching, mixing, transporting, placing, and curing. Improvements in techniques and equipment are making it harder for poor construction practices to exist, but exist they do, and vigilance on the part of those charged with the responsibility of this phase of construction is necessary.

Maintenance of the structure.—This merely means what it says: Inspection of the structure at regular intervals to determine whether unusual deterioration is taking place, and adequate protection or repair to minimize the deterioration.

The Role of Quality Control

Now, how does quality control enter into this picture? First, let us define what is meant by quality control. A definition that has been used by the author is as follows: Quality control as applied to construction is a system whereby construction is controlled by scientific methods rather than by chance. Scientific methods of investigation, testing, and analyzing provide criteria by which materials are evaluated and used in construction. Specifications for materials, methods of test, and standards of acceptance are established from these criteria. With realistic specifications designed for each specific job, adequate and impartial inspection of materials and methods, and statistical methods of analysis, best use can be made of the available materials. The owner can thus be assured of getting what he pays for in materials and construction, and the contractor knows what to expect in the way of inspection and control.

Quality control supervision of construction must be applied in much the same way as process quality control is applied in a manufacturing plant. That is, it must be independent of other departments working for management. However, it must not be looked upon as a "police action" with the quality control engineer checking up on everybody else, even though such checking up is sometimes necessary. Instead, the quality control engineer is on the job to help other responsible persons to get a good job and to perform

JOSEPH J. WADDELL is chief materials engineer for Soil Testing Services, Inc., Chicago, Ill., in charge of concrete and materials inspection and control. He was formerly engaged in consultation work in quality control of construction materials and was in charge of materials inspection and quality control for the general consultants on the Northern Illinois Toll Highway, Lake Pontchartrain Bridge, and many other projects. He was with the U. S. Bureau of Reclamation for 18 years in concrete inspection and control.

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* Presented at the Sixty-fourth Annual Meeting of the Society, June 25–30, 1961.

the necessary and approved functions as shown in Table I.

As shown in this table, construction quality control consists of three phases: (*A*) Preliminary Investigations, (*B*) Construction Inspection and Control, and (*C*) Solution of Special Problems. The objective of quality control is the construction, at minimum practicable cost, of structures in which quality is uniform and sufficient to ensure satisfactory service throughout the intended operating life. This objective is obtainable only through close and systematic control of all operations, from preliminary investigations, through selection and production of materials and all phases of construction, and finally through adequate maintenance. Of paramount importance is competent inspection and control during construction.

Quality control offers a coordinated procedure for control, from raw material procurement through processing to final acceptance, based on sound principles. It is designed to offer quality commensurate with the requirements of the work, avoiding both low quality that leads to deterioration, as well as costly excess quality. Control eliminates the use of substandard materials and applies common-sense considerations to the evaluation of materials that are borderline in quality.

The small cost of control is amortized through the years in lessened maintenance, longer structural life, greater safety, and better appearance. Indeed, appreciable savings in construction cost are possible when the job is properly controlled. By applying statistical quality control to concrete, it has been possible in some cases to reduce the amount of cement required per cubic yard of concrete, thus effecting a significant saving in cost.

Control of Concrete

Now let us see how this can be applied to the ready-mixed concrete industry.

A few years ago C. E. Proudley[1] reported the method used by the North Carolina State Highway Dept. for inspecting and rating ready-mix concrete plants. Briefly, that plan consists of an evaluation of each plant based on plant equipment and layout and on qualifications of plant employees. Inspection of plants prior to approval and periodically thereafter is made by personnel of the State Highway Dept. If a plant's equipment or services becomes unacceptable, it may result in removal of that plant from the approved list. Plant employees are qualified as concrete technicians through a training program conducted jointly by the industry and the Highway Dept. The Department also tests materials used by the approved plants.

Results have been most gratifying. Once the program was under way, the ready-mixed concrete operators soon realized the importance and value of an acceptable rating, with the result that requests for ratings came in from many plants. Similar plans have been or are being established by other states.

But what of the great volume of concrete that goes to the commercial market—small or occasional users, private engineering projects, and architectural uses? The quality of concrete is important to everyone—the individual who uses a few cubic yards in the construction of a home, the subdivision builder who should be giving his customers good quality materials, the taxpayer who is the ultimate owner of public works projects, and the stockholders of private industry who invest vast sums every year in new plant construction. It is in this field that much of the responsibility rests upon the producers, and it is through the producers that a quality control program must be put into effect. Quality control of ready-mixed concrete has long been a subject of discussion in the industry. To achieve real quality control requires that the industry itself take the responsibility of establishing a program that will ensure uniform production of concrete possessing the required characteristics. Such a program must be voluntary on the part of the individual ready-mixed concrete companies, and it must have the wholehearted support of the member companies. No halfhearted measures will do.

The objective of any such program is simply one of providing to the users of ready-mixed concrete the necessary assurance that the standards established by the industry are proper and that they are being followed. Many ready-mixed concrete producers already have their own quality control sections of varying degrees of effectiveness, and most producers consistently produce high-quality concrete. Individual companies are continually conducting their own programs to ensure consistently high-quality production. However, the responsibility should not rest upon individual companies, but rather upon the industry.

A Suggested Plan

In order to keep the program workable and to avoid unwieldiness resulting from sheer size, it is best if the program is applied on an area pattern, say one setup covering a large city and its metropolitan area. A suggested plan is as follows:

1. The first step is to explain the scope and method of the plan to interested companies in the area.
2. The next step is an inspection of all participant plants and explanation of the program to operating personnel. Each plant is evaluated on the basis of inspection, testing, and analysis of all operations from raw material procurement to delivery of concrete to the construction site. Data obtained in the evaluation of a plant is the confidential property of the evaluating officer and the plant management.
3. After this preliminary rating of all plants, an instruction school is held for all operating personnel of all plants, including supervisors whenever possible.
4. Six months after the preliminary ratings are first given, and after completion of the school, another evaluation of all plants is made, and all plants are officially rated.
5. A continuing, systematic method of inspection is established whereby all plants are kept under scrutiny at irregular intervals. Any changes in operation, personnel, materials, or equipment may be reflected in a change of rating. Any unapproved plant can request an inspection when there is reason to believe that the quality of operation has improved. On the other hand, a plant that is consistently barely within the approved limits may lose its rating if no effort is made to improve its operation.
6. The instruction school should be held about once a year.
7. It is essential that the program be publicized throughout the construction industry in the area served by the plants in the program. After all, it is the users of concrete that need to know about quality of concrete, so that they will insist that the producer deliver a quality product. At the same time, insistence upon quality inspection, performed by well-qualified inspectors and technicians, will do much to improve the quality of the whole concrete industry.

"To err is human." This might be paraphrased to read, "To vary is human." This is true of machines too. The probability of making two or more units of anything—machine screws, automobiles, or batches of concrete—exactly the same, is indeed infinitesimal. There are always variables, some large, some small. Quality control helps to level out these variables, taking the humps and hollows out of the quality curve. The result is greater uniformity which leads to better construction at less cost.

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[1] C. E. Proudley, "Qualification Plan for Ready-Mixed Concrete Plants," *Journal*, Am. Concrete Inst., *Proceedings*, Vol. 55, May, 1959, pp. 1165–1172.

A Study of the Centrifuge Test for Determining the Cement Content of Fresh Concrete

By STANTON WALKER, D. L. BLOEM, R. D. GAYNOR, and J. R. WILSON

An evaluation of the centrifuge test for cement content of fresh concrete is presented. Background experiences which led to refinements in procedure are discussed, and data are presented from laboratory tests on concretes of various cement factors. With meticulous care in testing, proper calibration, and appropriate correction for sampling errors in the small test portions, the method can be made to provide an accurate and reproducible measure of the cement in a typical size sample of concrete. Such reliability can be expected only under optimum conditions. The utility of the test as a check on cement content of field-size batches is further limited by the doubtful representativeness of concrete samples secured under field conditions. The centrifuge test does offer promise as a method of measuring within-batch uniformity of concrete as an evaluation of mixer efficiency.

THERE IS need for a practical method for the accurate determination of cement content of fresh concrete. Inspection could be much simplified and the existing overemphasis on strength as an acceptance criterion reduced if cement factor could be measured quickly. Past attempts at developing such a test have met with little success. Dunagan (1)[1] in 1929, described a method based on differences in the specific gravities of the solids in the concrete. Others have approached the problem by making sieve analyses of the fresh concrete (2–7). These procedures have not been widely used; they are cumbersome and not satistactorily accurate.

In 1955 a new and unique approach described by Hime and Willis (8), involved washing the cement, with some fine sand, from a sample of concrete, drying the cement-sand mixture, and then separating the cement by centrifuging in a liquid denser than the sand but less dense than the cement. Interest in the procedure was extensive and led to the preparation and publication of a proposed standard method by Subcommittee III-c on Methods of Testing Fresh Concrete of ASTM Committee C-9 on Concrete and Concrete Aggregates (9).

Up to this time, work with the Hime-Willis test has been largely developmental and exploratory. Its authors early recognized and described the need for reserve in attempts to use the method to measure cement under field conditons. While the test gave good information on the small batches of concrete (4 to 5 lb) used in its development, the difficulty of securing such small samples to represent a large batch caused concern. Another important limitation is the need to "calibrate" the centrifuging operation for the particular set of concrete ingredients and range of mixture proportions to be tested.

It seems clear that the centrifuge test can be useful in concrete research

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

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and, within its limitations, in certain testing of field-size batches. However, to consider it as a procedure to "police" cement content in its present state of development does not appear to be justified. Further checking, particularly on making the small samples representative of large batches, is needed if the test is not to lead to confusion and injustice. Its limitations should be clearly spelled out to prevent its use where it is not applicable.

This paper discusses research to evaluate the accuracy and reproducibility of the centrifuge test. The work was conducted at the Joint Research Laboratory of the National Sand and Gravel Assn. and the National Ready Mixed Concrete Assn., at the University of Maryland.

Exploratory Tests

A first group of laboratory tests, limited in scope, served to acquaint laboratory personnel with techniques and to reveal potential pitfalls. Results of multiple tests on a given batch of concrete were found to vary among themselves and often to differ greatly from the known cement content. However, much of the latter error was found to be caused by the tendency to include a more-than-representative proportion of coarse aggregate in the small samples used for test. When correction was made for this sampling error, agreement between actual and measured cement contents was improved.

Further preliminary work involved an attempt to determine how reliable a measure of cement content the centrifuge test would provide under field conditions. Producers of ready-mixed concrete were asked to sample batches of known characteristics, process the samples through the drying stage, and then send them to the laboratory for centrifuging. The test results were not informative. Apparently the samples were not dried soon enough or thoroughly enough to prevent some hydration of cement. As a result, reproducible separations in the centrifuge could not be made.

Experience in the preliminary studies revealed several particularly vulnerable areas in the centrifuge method, requiring special care or modification of procedure. Securing a representative concrete sample of only about 4 lb was found to be difficult if not impossible. Special care was exercised in the sampling: the 1-cu-ft batches (which would be analogous to typical-size field samples) were placed on flat steel trays and, after remixing, were sampled by means of a flat scoop of rectangular cross-section pushed through the full depth of the concrete. This reduced but did not completely eliminate sampling error, as clearly demonstrated by differences in the amount of coarse aggregate found in the sample in relation to the proportion known to have been used in the batch. By measuring the coarse aggregate in the sample, a correction for this error was made.

It was found necessary to siphon rather than decant excess water from the minus No. 30 fraction which had been washed from the concrete. Decantation disturbed the surface of the settled material, causing some of it to be lost.

Drying of the cement-sand mixture was a critical operation. The ordinary burner of a gas hot plate provided inadequate heat (only about 10,000 to 15,000 Btu per hr). It was replaced with a unit from a hot water heater to bring the rating above the 30,000 Btu per hr recommended in the proposed method. When drying was inadequate, lumps were difficult to break up. The agglomerations, though very fine, contained both sand and cement, and hence produced inaccuracies in the centrifuge separations.

Even with ample drying, it was necessary to exercise great care in pulverizing the cement-sand mixture before centrifuging. The procedure finally adopted consisted of repeated alternations of rolling under a medium-hard rubber pad on a flat surface and rubbing gently over the surface of a No. 100 sieve until all cement was separated from the sand particles.

Securing a representative portion of the dried material also presented problems. Use of a spatula as recommended in the published procedure apparently led to segregation, with the coarser sand grains tending to roll off the sloping surface of the heaped mixture. A sampling scoop of thin sheet metal was devised, rectangular in cross-section with a width of about $\frac{3}{8}$ in. and depth of $\frac{3}{4}$ in. Inserting this repeatedly into the well-mixed dry material apparently yielded a more representative portion.

Removal of the sand floating on the heavy liquid after centrifuging could not be done without at least some sticking of grains to the tube. The problem was minimized by using a spatula, with cross-section curved to the radius of the tube, to scoop out most of the sand. The heavy liquid was then carefully decanted while rotating the tube to cause the adhering sand grains to be washed out. The cement was firmly enough embedded that, with care, this decantation process could be accomplished without disturbing the cement. In washing the sand in acetone to remove the heavy liquid, as required by the proposed method, there was some tendency for sand grains to remain suspended because of the fairly high specific gravity of the liquid mixture. After the first washing, the gravity decreased because of greater dilution of the heavy liquid, and there was less risk of sand being washed away.

Current Investigations

These experiences made it clear that dependable and reproducible results can be secured only by the most meticulous adherence to optimum procedures. They left no doubt of the complete unreliability of results secured by other than trained technicians working under laboratory conditions.

With this background, two investigations were outlined—one to be carried out wholly in the laboratory and the other to involve field concrete with centrifuge separations and other tests being conducted in the laboratory. The first (laboratory) portion has been completed and the results are reported here. The second investigation is still in progress.

Even though the field test data cannot be reported at this time, it should be of interest to describe what is being done. Samples of concrete are being taken from normally produced batches of ready-mixed concrete used on local construction. No attempt is made to regulate the mixtures or the production procedures, although information is collected on all phases of the operation which might affect the quality and uniformity of the concrete. Samples are taken from different portions of the batch and the following tests are made:

1. Slump.
2. Air content (pressure method).
3. Weight per cubic foot.
4. Wash test to measure coarse aggregate in unit-weight sample.
5. Air-free unit weight of mortar.
6. Drying of fresh concrete sample for determination of water content, followed by washing and sieve analysis of solid ingredients.
7. Centrifuge cement content, supplemented by drying and sieving of coarse sizes to provide correction for sampling error and estimate of water content.
8. Compressive strength at 7 days.

Thus, information will be secured comparing the centrifuge test with the several other measures of uniformity.

Outline of Laboratory Tests

The tests reported here involved small batches of concrete mixed and tested in the laboratory. The "test batches" were 1 cu ft in volume, mixed in a small tilting mixer. Parallel "calibration batches," weighing 2000 g and having the same proportions as the 1-cu-ft batches, were hand mixed. Concretes of three cement factors—3, 5, and 7 bags per cu yd—were made.

The aggregates were quartz sand and gravel. The gravel was separated into three sizes and recombined, for each

TABLE I.—CHARACTERISTICS OF FRESH CONCRETE.[a]

Nominal Cement, bags per cu yd	Round	Weight, lb per cu ft	Air Content, per cent	Slump, in.	Cement, bags per cu yd: As Batched	Cement, bags per cu yd: As Discharged: Assumed[b]	Cement, bags per cu yd: As Discharged: Corrected[c]	Mixing Water as Batched: gal per cu yd	Mixing Water as Batched: gal per bag
3	A	142.0	3.8	2.5	3.01	2.96	2.94	35.5	11.8
	B	141.6	3.7	3.5	3.00	2.95	2.93	36.3	12.1
	C	141.8	3.7	2.2	3.01	2.95	2.91	36.3	12.0
	D	141.7	3.6	5.0	3.00	2.95	2.92	36.4	12.1
	E	142.1	3.4	2.4	3.01	2.96	2.93	36.4	12.1
	Avg	141.8	3.6	3.1	3.01	2.95	2.93	36.2	12.0
5	A	145.1	2.6	4.5	5.02	4.92	4.81	35.4	7.0
	B	145.1	2.8	4.0	5.03	4.92	4.88	34.6	6.9
	C	145.4	2.7	3.0	5.03	4.94	4.90	34.6	6.9
	D	145.5	3.0	3.6	5.06	4.95	4.89	33.9	6.7
	E	145.5	3.0	2.8	5.06	4.95	4.91	33.9	6.7
	Avg	145.3	2.8	3.6	5.04	4.94	4.88	34.5	6.8
7	A	147.1	2.1	4.1	7.11	6.95	6.99	35.5	5.0
	B	147.3	2.2	3.5	7.13	6.95	6.94	35.1	4.9
	C	147.1	2.4	3.0	7.11	6.93	6.88	36.0	5.1
	D	147.2	2.1	3.3	7.12	6.95	6.91	35.2	5.0
	E	147.1	2.0	3.5	7.11	6.95	6.90	35.5	5.0
	Avg	147.2	2.2	3.5	7.12	6.95	6.92	35.5	5.0

[a] Concrete mixed 6 min in 1-cu-ft batches in small tilting mixer. Coarse aggregate comprised 0.65 cu ft, dry-rodded, per cu ft of concrete ($b/b_o = 0.65$). The fine aggregate as batched was 44.2, 42.3, and 39.7 per cent by weight of total aggregate for the 3-, 5-, and 7-bag concretes, respectively.

[b] Based on assumption that mortar retained in mixer was representative of the minus No. 4 portion of the concrete as batched.

[c] Based on analysis of the mortar actually retained in the mixer.

TABLE II.—TESTS OF 2000-G HAND-MIXED BATCHES.[a]

Nominal Cement, bags per cu yd	Round	Weight of Dry Material in 2000-g Batches, g: Cement	Weight of Dry Material in 2000-g Batches, g: Total Cement and Aggregates	Cement Indicated by Centrifuging, g: Tube 1	Cement Indicated by Centrifuging, g: Tube 2	Cement Indicated by Centrifuging, g: Avg	Cement Indicated by Centrifuging, g: Coefficient of Variation[d]	Total Dry Materials Recovered, g
3	A	144[b]	1832[b]	166	161	164	2.7	1823
	B	...	...	161	169	165	4.3	1824
	C	...	...	163	163	163	0.0	1821
	D	...	...	151	153	152	1.2	1825
	E	...	...	154	152	153	1.2	1826
	Avg			159	160	159	1.9	1824
Coefficient of Variation, per cent[e]						3.9		
5	A	237[b]	1838[b]	235	236	236	0.4	1828
	B	...	...	242	239	242	1.1	1827
	C	...	...	252	248	250	1.4	1826
	D	...	...	243	245	244	0.7	1829
	E1[c]	...	...	259	238	248	7.5	1828
	E2[c]	...	...	230	235	232	1.9	...
	Avg			244	240	242	2.2	1828
Coefficient of Variation, per cent[e]						2.1		
7	A	329[b]	1845[b]	285[f]	285[f]	285[f]	0.0	1735[f]
	B1[c]	...	...	343	333	338	2.6	1830
	B2[c]	...	...	328	323	325	1.4	...
	C	...	...	330	334	332	1.1	1832
	D	...	...	326	324	325	0.6	1832
	E	...	...	328	333	330	1.3	1833
	Avg			331	329	330	1.4	1832
Coefficient of Variation, per cent[e]						1.0		

[a] Concrete proportions same as for corresponding 1-cu-ft batches described in Table I. Data used as basis for correcting results of centrifuge samples taken from 1-cu-ft batches.

[b] Actual amounts weighed into batch.

[c] Duplicate centrifuge determinations on same batch.

[d] Equals 0.8865 times the difference between the two tubes, expressed as a percentage of their average.

[e] $\frac{100}{\bar{x}}\sqrt{\frac{\Sigma(\bar{x} - x)^2}{n-1}}$,

where: x is the indicated cement weight for a given round, $\bar{x}$ is the average cement weight for the particular nominal cement factor, and n is the number of usable rounds.

[f] Data discarded.

batch, to consist of equal parts of $\frac{3}{8}$ to $\frac{1}{2}$ in., $\frac{1}{2}$ to $\frac{3}{4}$ in., and $\frac{3}{4}$ to 1 in. The sand was well graded to the No. 4 sieve and had a fineness modulus of approximately 2.70. The gap between the fine and coarse aggregates facilitated separating the two during the analysis of the concrete. The concrete was designed to contain 0.65 volume of dry rodded coarse aggregate per unit volume of concrete ($b/b_o = 0.65$) and to have a slump of 3 to 4 in. Five rounds were made on separate days for all conditions.

The 1-cu-ft batches were mixed for 6 min in a small tilting mixer and discharged into a flat metal tray. Three samples of approximately 2000 g each were taken from each batch for centrifuge tests, with all possible precautions being exercised to assure that they were representative. The remainder of the batch was tested for slump and unit weight, the latter being measured in a $\frac{1}{2}$-cu-ft container. After the batch had been discharged, all material (cement, water, and sand) adhering to the interior of the mixer was washed into a container and allowed to settle. The solids were recovered and dried and the cement content determined by centrifuging. These data were used to make corrections in mixture characteristics as described later.

The centrifuge tests were made in accordance with the proposed method (9). The concrete samples were washed in a basket of 30-mesh sieve cloth to separate the fine material, including cement, from the coarser fractions. This fine material was allowed to settle, excess water was siphoned off, and the solids were dried by heating in a heavy frying pan over a gas hot plate. Two 20-g portions of the dried mortar from each sample were used in the centrifuge determination of cement. The concrete from the $\frac{1}{2}$ cu ft unit weight sample was washed over a $\frac{5}{16}$-in. sieve, and the material retained was dried, re-sieved, and weighed. A similar determination of coarse aggregate was also made on the coarse fraction remaining after washing the centrifuge samples.

Discussion of Test Data

The test data are summarized in Tables I through VI. Table I gives the characteristics of the fresh concrete. The batch weights included an allowance for predicted "holdback"—the material coating the interior of the mixer drum after discharge of the batch. As noted earlier, the holdback was centrifuged and its cement content measured. Therefore, cement factors calculated on three bases are tabulated in Table I: (1) as batched, (2) as corrected for predicted holdback, and (3) as corrected for the amount of cement found in the material coating the mixer

TABLE III.—CENTRIFUGE DETERMINATIONS OF CEMENT FACTORS FROM 1-CU-FT BATCHES.[a]

Nominal Cement, bags per cu yd	Round	Actual Cement, bags per cu yd[b]	Cement, bags per cu yd, Determined from Centrifuge Samples					
			As Measured		Corrected for Calibration: Not Adjusted for Coarse Aggregate		Corrected for Calibration: Adjusted for Coarse Aggregate	
			Avg	Range[c]	Avg	Range[c]	Avg	Range[c]
3..........	A	2.94	3.15	0.42	2.85	0.38	2.84	0.33
	B	2.93	3.21	0.36	2.90	0.33	2.82	0.17
	C	2.91	3.37	0.30	3.05	0.27	2.89	0.08
	D	2.92	3.07	0.06	2.78	0.05	2.82	0.08
	E	2.93	3.16	0.21	2.86	0.19	2.84	0.01
	Avg	2.93	3.19	0.27	2.89	0.24	2.84	0.13
Over-all range, bags per cu yd[d]............				0.65		0.59		0.33
5..........	A	4.81	4.96	0.15	4.86	0.15	4.95	0.16
	B	4.88	5.12	0.12	5.01	0.12	4.91	0.05
	C	4.90	5.17	0.30	5.06	0.29	4.92	0.06
	D	4.89	4.85	0.24	4.75	0.23	4.89	0.18
	E	4.91	5.08	0.28	4.97	0.27	5.02	0.26
	Avg	4.88	5.04	0.22	4.93	0.21	4.94	0.14
Over-all range, bags per cu yd[d]............				0.61		0.60		0.38
7..........	A	6.99	6.66	0.08	6.64	0.08	6.76	0.11
	B	6.94	6.71	0.34	6.69	0.34	6.95	0.18
	C	6.88	6.72	0.29	6.70	0.29	6.73	0.20
	D	6.91	6.96	0.31	6.94	0.31	6.86	0.20
	E	6.90	6.69	0.26	6.67	0.26	6.90	0.08
	Avg	6.92	6.75	0.26	6.73	0.26	6.84	0.15
Over-all range, bags per cu yd[d]............				0.56		0.56		0.42

[a] Centrifuge values for each round represent averages for 3 samples from the same batch.
[b] Best estimate of true cement factor of concrete from which centrifuge samples were taken; corrected value from Table I.
[c] Maximum difference among 3 samples from same batch.
[d] Maximum difference among 15 samples representing all 5 batches with the same nominal cement factor.

TABLE IV.—ESTIMATES OF VARIABILITY OF CENTRIFUGE TESTS FOR CEMENT CONTENT.

Nominal Cement, bags per cu yd	Standard Deviation, bags per cu yd, based on: 15 tests taken individually[a]	5 averages of 3 tests each, corrected to single test[b]	Average of ranges for sets of 3 tests[c]	Over-all range of 15 tests[d]
Not Corrected for Coarse Aggregate Error in Samples				
3........	0.17	0.19	0.16	0.19
5........	0.15	0.22	0.13	0.18
7........	0.17	0.20	0.15	0.16
Avg.......	0.16	0.20	0.15	0.18
Corrected for Coarse Aggregate Content of Samples				
3........	0.08	0.05	0.08	0.10
5........	0.09	0.09	0.08	0.11
7........	0.10	0.16	0.09	0.12
Avg.......	0.09	0.10	0.08	0.11

Note.—Analysis of variance indicates that, in these tests, variability in measured cement for single samples from different batches was not significantly greater ($\alpha = 0.05$) than the variability for samples from the same batch. Based on the assumption that the 15 tests for a given cement factor (3 from each of 5 batches) represent the same population, the four different standard deviations in the table all provide a measure of variability for single tests.

[a] $$\sigma_1 = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

where:
x = measured cement factor for an individual test,
$\bar{x}$ = average cement factor for all 15 tests, and
n = total number of tests (15).

[b] $$\sigma_2 = \sqrt{\frac{3\Sigma(x_a - \bar{x})^2}{n_a - 1}}$$

where:
x_a = average of the 3 tests made on a given batch,
$\bar{x}$ = over-all average for the 5 batches (same as $\bar{x}$ used for σ_1), and
n_a = number of batches, 5.

[c] $\sigma_3 = 0.5907\bar{R}_3$

where:
$\bar{R}$ = average of the ranges in cement factor for sets of 3 tests from the same batch (see the "Range" columns of Table III).

[d] $\sigma_4 = 0.2880R_{15}$, where: R_{15}, = over-all range in cement factor for all 15 tests.

drum. The last value is the best estimate of the actual cement content of the concrete used in the centrifuge tests. Note that, for any one of the three bases of calculation, the range in cement factor among the five rounds is so small as to be insignificant.

Table II gives results of the so-called "calibration" tests of the 2000-g hand-mixed batches. Five batches, indicated as rounds A through E, were made for each cement factor, and two 20-g portions were centrifuged for each batch. The amount of cement determined by centrifuging is shown in the table as well as the total weight of dry material recovered from the 2000-g samples. For comparison, the amounts of cement and of total dry materials actually weighed into each 2000-g batch are given.

The calibration data show excellent reproducibility between the two tubes for each sample; the average coefficients of variation are 1.9, 2.2, and 1.4 per cent for the 3-, 5-, and 7-bag concretes, respectively. The reproducibility from round to round was also good as shown by coefficients of variation for averages of two tubes of 3.9, 2.1, and 1.0 per cent for the 3-, 5-, and 7-bag concretes, respectively.

The significant feature of Table II is the comparison between the cement content as determined by centrifuging and that which was actually weighed into the 2000-g batch. For the 5- and 7-bag concretes the agreement is good—242 and 330 g determined as compared with actual weights of 237 and 329. For the 3-bag concrete, the agreement was not so good, being 159 g determined content as compared with 144 g actual content.

Further tests are being made to determine the sources of these discrepancies, particularly for the 3-bag mix. However, the differences found, regardless of their cause, were used to establish correction factors for the centrifuge tests on the 1-cu-ft batches. Values as measured were corrected by multiplying by the following factors; 3-bag concrete, 144/159 (about 0.91); 5-bag concrete, 237/242 (about 0.98); and 7-bag concrete, 329/330 (about 1.00).

Table III summarizes the principal data for evaluating the centrifuge test. It compares actual cement contents with those determined by centrifuging. The "actual" cement contents represent the best estimates for the 1 cu ft batches—the "corrected" values from Table I. The centrifuge test cement factors are reported: (1) as measured, (2) as corrected by the calibration factor discussed above, and (3) as corrected both for calibration and for the coarse aggregate contents of the centrifuge samples.

TABLE V.—CENTRIFUGE DETERMINATIONS OF MIXING WATER IN 1-CU-FT BATCHES.

Nominal Cement, bags per cu yd	Round	Actual Mixing Water, gal per cu yd[a]	Water, gal per cu yd Determined from Centrifuge Samples			
			As Measured		Corrected for Calibration	
			Average	Range[b]	Not Adjusted for Coarse Aggregate	Adjusted for Coarse Aggregate
3	A	33.9	35.8	1.0	33.9	33.8
	B	35.3	38.3	3.3	36.4	35.4
	C	35.5	37.8	2.1	35.9	34.1
	D	34.5	35.4	0.4	33.5	34.0
	E	35.4	35.5	1.9	33.6	33.4
	Average	34.9	36.6	1.7	34.7	34.1
Over-all range, gal per cu yd[c]				5.6		
5	A	34.6	35.0	2.2	32.6	33.2
	B	32.5	36.9	0.6	34.5	33.7
	C	32.6	35.1	2.0	32.6	31.8
	D	32.5	33.2	1.5	30.7	31.2
	E	32.0	32.9	2.0	30.4	30.6
	Average	32.8	34.6	1.7	32.2	32.1
Over-all range, gal per cu yd[c]				5.2		
7	A	32.7	34.8	2.0	31.8	33.0
	B	33.3	35.0	2.6	32.0	33.2
	C	34.4	35.7	0.6	32.7	32.9
	D	33.7	36.0	2.6	32.8	32.4
	E	34.6	34.2	2.2	31.1	32.7
	Average	33.7	35.1	2.0	32.1	32.8
Over-all range, gal per cu yd[c]				4.5		

[a] Best estimate of true mixing water content of concrete from which centrifuge samples were taken.
[b] Maximum difference among 3 samples from same batch.
[c] Maximum difference among 15 samples representing all 5 batches, with the same nominal cement factor.

TABLE VI.—QUANTITY OF COARSE AGGREGATE IN CONCRETE.

Nominal Cement, bags per cu yd	Round	Coarse Aggregate, Per Cent of Weight of Concrete				
		In 1-cu-ft Batches				
		As Batched	As Discharged		Sieved from ½-cu-ft Sample	In Centrifuge Sample[c]
			Assumed[a]	Corrected[b]		
3	A	47.3	48.3	48.3	49.5	48.2
	B	47.2	48.2	48.2	49.6	46.8
	C	47.2	48.2	48.2	48.7	45.4
	D	47.2	48.2	48.2	49.5	48.9
	E	47.2	48.2	48.2	49.2	47.9
	Avg.	47.2	48.2	48.2	49.3	47.4
5	A	46.4	47.5	47.5	48.9	48.5
	B	46.5	47.6	47.6	48.4	46.4
	C	46.5	47.6	47.6	48.1	46.2
	D	46.5	47.7	47.7	48.8	48.5
	E	46.5	47.7	47.7	48.0	48.1
	Avg.	46.5	47.6	47.6	48.4	47.5
7	A	45.6	46.8	46.8	47.3	48.7
	B	45.7	46.9	46.9	47.5	48.8
	C	45.6	46.9	46.9	47.6	47.3
	D	45.7	46.9	46.9	47.0	46.2
	E	45.6	46.8	46.8	47.3	48.7
	Avg.	45.6	46.9	46.9	47.3	47.9

[a] Based on assumption that mortar retained in mixer was representative of the minus No. 4 portion of the concrete as batched.
[b] Based on analysis of the mortar actually retained in the mixer.
[c] Average for three samples.

The last value needs explanation. The amount of coarse aggregate used in the 1-cu-ft batches was accurately known. However, the proportion of coarse aggregate measured in the small centrifuge test samples often differed from that actually in the batch. Thus, even for a batch as small as this, it was impossible to secure a truly representative 2000-g sample for centrifuging.

It is apparent that the results of the centrifuge tests, in order to reveal actual cement content, must reflect the true coarse aggregate ratio of the concrete sampled. Accordingly, cement as measured must not only be corrected for the calibration factor but also for any discrepancies in the quantity of coarse aggregate in the centrifuge sample. The correction is made by multiplying by the ratio:

$$\frac{100 - C_a}{100 - C_s}$$

where:

C_a = actual per cent by weight of the coarse aggregate in the concrete batch, and

C_s = per cent by weight of coarse aggregate in the centrifuge sample.

Included in Table III are ranges in measured cement factor for the three samples from each batch and for the 15 samples representing all five batches of a given class of concrete. While the ranges are not a good statistical index of reproducibility, they do provide interesting information, particularly on reliability of tests from a given batch. Slightly more refined statistical data are discussed later in connection with Table IV.

Average ranges in centrifuge cement factors for three samples from the same batch, as measured and without correction, were 0.27, 0.22, and 0.26 bags per cu yd for 3-, 5-, and 7-bag mixes, respectively. The corresponding over-all ranges for 15 samples were 0.65, 0.61, and 0.56 bags per cu yd. The ranges in cement factor, with values corrected for calibration, are of course related to the uncorrected ranges above by the correction ratio discussed earlier. For the 3-, 5-, and 7-bag mixes, respectively, the average within-batch ranges were 0.24, 0.21, and 0.26 bags per cu yd, and the over-all ranges were 0.59, 0.60, and 0.56. Considering all of the ranges, it appears that variations in measured cement on a given sample did not differ greatly with cement factor level. The average variation, when coarse aggregate sampling error was not taken into account, is indicated by a spread of about 0.24 bag of cement per cu yd among the samples from the same 1-cu-ft batch. The over-all range for 15 samples has little practical significance except as it relates to other computations discussed later.

Table III shows clearly the considerable improvement in centrifuge test reproducibility resulting from correction for coarse aggregate content of the test sample. The average range for three tests on the same batch was reduced almost by half, to 0.13, 0.14, and 0.15 bag per cu yd for nominal cement factor levels of 3, 5, and 7, respectively. The over-all range for 15 samples was correspondingly reduced to 0.33, 0.38, and 0.42 bag per cu yd. Thus, the over-all average range for three tests was reduced from 0.24 to 0.14 bag per cu yd by the simple aggregate correction.

The accuracy of the centrifuge test, as would be expected from earlier discussion, was greatly improved by the use of calibration factors. "As measured" values, without correction, differed from actual values by as much

as 0.26 bag, based on the average of five rounds. Use of the calibration factors improved accuracy for the two leaner mixes, but did not affect the 7-bag concrete where the calibration ratio was substantially 1.00. With calibration taken into account, the maximum error in average cement factor was 0.19 bag per cu yd, for the rich concrete. When results were further corrected for coarse aggregate content of centrifuge samples, the error in average cement factor was never as large as 0.1 bag per cu yd. Summarizing, it can be said that calibration corrections are more important in lean than in rich mixes. With regard to coarse aggregate sampling errors, the reverse is true—nonrepresentativeness of coarse aggregate quantity tends to be somewhat more pronounced in the richer concretes.

Table IV provides additional, slightly more refined data on the reliability of the centrifuge test. They indicate the ability of the method to measure cement in samples consisting of about 1 cu ft of concrete. A separate problem, not encompassed in this study, is that of securing a representative sample of, say, 1 cu ft or thereabouts, from a several-cubic-yard batch of concrete in the field.

By statistical procedures which need not be presented here, it can be shown that, in this investigation, the test-to-test variability of centrifuge cement content was not significantly greater for tests from different batches of a given nominal mix than for tests from the same batch. If we accept this premise (that we can consider all 15 tests for a given mix as coming from the same population), we can calculate standard deviations on the four bases shown in Table IV. The formulas for the calculations are given in the table for those interested and will not be discussed in detail. Suffice it to say that the general agreement of the four calculated values lends credence to their validity as indications of the reproducibility of single tests on a given sample of concrete.

Table IV indicates that, without correction for coarse aggregate error, the centrifuge test yields a standard deviation in cement content of about 0.2 bag per cu yd. This means that, for a "normal" distribution, about $\frac{2}{3}$ of single tests from a given sample will lie within 0.2 bag of the average; 95 per cent will be within 0.4 bag, and 99 per cent within a half bag.

Correction for coarse aggregate content cuts the standard deviation approximately in half, to 0.1 bag per cu yd. Therefore, 99 per cent of the test results would be expected to lie within about $\frac{1}{4}$ bag of the average. Keep in mind that this excellent reproducibility applies only to meticulously made tests, corrected on the basis of accurate calibration data as well as for the error in coarse aggregate content of the small centrifuge test sample. Further, the cement factor determined applies only to the sample (in this case 1 cu ft) tested. Its quantitative significance as a test of a field batch of concrete would depend upon how well the sample duplicated the composition of its prototype.

Tables V compares the mixing water determinations on the concrete in much the same fashion as cement factors are compared in Table III. The "as measured" values are higher than actual batched quantities, probably because of the loss of small quantities of solids during the washing and drying operations. These quantities would appear as excess mixing water, since the determination involves subtraction of the weight of dried solids from the weight of the fresh concrete comprising the centrifuge sample. The apparent loss of solids is taken into account in the calibration correction, which brings the determined mixing water into reasonably good agreement with the actual. Further refinement is secured by adjusting for the error in coarse aggregate content of the centrifuge test samples. This fully corrected value, shown in the last column of Table V, averages 0.7 to 0.9 gal per cu yd less than the actual mixing water content, possibly reflecting some constant error inherent in the procedure or in basic assumptions. Ranges in mixing water, shown only for the "as measured" values, indicate a degree of reproducibility comparable with cement content measurements, discussed earlier.

Table VI compares the percentage of coarse aggregate in the concrete as determined in the several manners indicated. Reasonably good agreement is shown throughout except that the percentages revealed by the $\frac{1}{2}$ cu ft unit weight samples (one half the entire batch) were higher than the quantity batched by about 2 percentage points. That difference does not seem great but was so consistent as to suggest a disturbing tendency in sampling. The concrete was proportioned to avoid ambiguity as to what constituted coarse aggregate. All of the gravel as batched was retained on a $\frac{3}{8}$-in. sieve and the sand was passed through a No. 4 sieve. Determinations of coarse aggregate in the unit weight and centrifuge samples were made using a $\frac{5}{16}$-in. sieve. The high coarse-aggregate content in the samples indicates a tendency to include gravel and leave too much mortar. If this is a typical inclination of testing technicians, it will tend to result in lower-than-actual measured cement contents unless a correction is made.

Summary and Conclusions

1. The tests reported here dealt only with concrete mixed in small batches in the laboratory. All tests were made by experienced laboratory technicians who were well equipped and were working under close supervision.

2. On the average, the centrifuge test provided a reasonably accurate measure of actual cement factor of the concrete sample upon which the test was made, provided corrections were applied for calibration of the test and for inability of the small centrifuge samples to represent accurately the coarse aggregate content of the concrete.

3. Under the favorable conditions employed, reproducibility of the cement content determinations was good, as indicated by the following standard deviations for single tests: approximately 0.2 bag per cu yd for "as measured" values, without correction for coarse aggregate content of the centrifuge samples; approximately 0.1 bag per cu yd for fully corrected results, taking into account coarse aggregate sampling errors.

4. The tests do not justify the conclusion that the centrifuge method is applicable as a quantitative measure of the cement content of large batches. In this connection, the following observations may be made:

(a) Securing representative 4-lb samples from a 1-cu-ft laboratory batch was difficult even with the exercise of meticulous care. It seems evident that the difficulty would be compounded for samples taken in the field from large mixers.

(b) The information necessary for making "calibration corrections" is not likely to be readily available and, at best, is inconvenient to obtain.

(c) Results of centrifuge tests, to be at all reliable, would require correction for coarse aggregate content of the small samples, based on some knowledge or assumption of accurate values.

5. The study suggests that the centrifuge method may have much merit as a research tool in the hands of experienced laboratory technicians provided with proper equipment.

6. A potential field application of the test would be to measure uniformity of concrete, if a sufficient number of samples were taken to assure representativeness. Within-batch variations might be measured and gross differences between batches of given proportions might be revealed.

Acknowledgments:

The laboratory investigation was conducted under the immediate direction of H. L. Knoppel, Jr., assistant laboratory manager. Milton Wills,

Graduate Fellow of the NSGA-NRMCA Research Foundation at the University of Maryland, assisted with the calculations and compilation of data.

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Expression of Stress-Rupture Data with Functions Derived by the Least-Squares Method

By M. J. STUTZMAN and J. W. FABER

Stress-rupture test data are reported in the three variables: temperature, stress, and time-to-rupture. Extensive research has been devoted to the evaluation of such data, and a variety of equations have been proposed to simplify the evaluation. The Larson-Miller parameter has been used extensively to express the time-temperature variables as a function which is plotted against stress on the master-rupture graph.

The least-squares method was used to calculate the line of minimum deviation from all of the test data determined at varied temperatures and stresses. The nominal 95 per cent confidence band was calculated from deviations of test data from the minimum deviation line. Data that follow a straight line (Stellite 31) and data that follow a parabolic curve (Nicrotung) are illustrated. Applications of the minimum deviation functions for the calculation of the representative stress for a definite time-to-rupture at a given temperature and for extrapolating stress-rupture data are discussed and illustrated.

THE STRESS-RUPTURE test is used extensively to evaluate alloys and processing methods for elevated-temperature applications. The data obtained by these tests become rather difficult to evaluate and present in terms of the three variables: temperature, stress, and time-to-rupture.

It has become common practice to plot stress-rupture data on a master-rupture graph using the Larson-Miller[1] parameter which combines the time and temperature variables by the expression

$$P(parameter) = T(20 + \log t)10^{-3}$$

where:

T = temperature, deg R, and
t = time to rupture, hr.

The purpose in describing this method of analyzing stress-rupture data is to present a practical method which can be plotted on a master-rupture graph and used as a guide for design purposes.

The normal procedure for the statistical analysis of stress-rupture data, including the determination of the 95 per cent confidence limits, uses a large number of tests at constant temperature and stress. A method for evaluating a function for the line of minimum deviation for stress-rupture data was previously presented.[2] In this method all of the data measured at varied temperatures and stresses were utilized. A nominal 95 per cent confidence band was then calculated from the deviations of test data from the line of minimum deviation.

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TABLE I.—REPRESENTATIVE STRESS-RUPTURE DATA FOR AIR-CAST STELLITE 31 WITH STATISTICAL ANALYSIS DATA.

Temperature, deg Fahr	Stress, psi	Time, hr	$y = \log S$	$x = P$	x^2	xy	Calculated y	Deviation, d	d^2
1350	43 000	126.0	4.63347	39.99	1599.2001	185.29247	4.62253	+0.01094	0.0001188
1500	26 000	123.2	4.41497	43.28	1873.1584	191.07990	4.39428	+0.02069	0.0004285
1600	16 000	167.0	4.20412	45.76	2093.9776	192.38053	4.22221	−0.01809	0.0003276
1700	12 000	191.8	4.07918	48.12	2315.5344	196.29014	4.05847	+0.02071	0.0004285
1800	9 000	134.2	3.95424	50.00	2500.0000	197.71200	3.92804	+0.02620	0.0006864
Totals for 33 tests			140.34425	1495.50	68066.7172	6339.8041			0.0324327

In this paper the method of determining equations for the line of minimum deviation, the limits of a nominal 95 per cent confidence band, and applications of these equations are presented. Stress-rupture data that follow straight-line and parabolic functions are discussed. The paper also defines a method of converting test data to the equivalent stress for a designated time-to-rupture at a given temperature.

It is fully recognized that the function used to express the data and the evaluation of the constants in these equations are not in strict accordance with standard statistical analysis methods. However, a function in three variables, time, temperature, and stress, was evaluated for Stellite 31 and plotted on the master-rupture graph with exceptionally close agreement with the minimum deviation line shown.

Analysis of Stress-Rupture Data That Follow a Straight-Line Function

Data for air-cast Stellite 31 previously reported[2] follow a straight-line function when plotted on a master-rupture graph as shown in Fig. 1. These data follow a straight-line relation represented by the equation

$$y = A + Bx \quad \ldots\ldots\ldots\ldots (1)$$

where:
$y = \log S$ (S = stress),
$x = P$ (Larson-Miller parameter), and
A and B = constants.

Since the test points will deviate from the line, the individual tests may be expressed by the equation

$$y \pm d = A + Bx \quad \ldots\ldots\ldots (2)$$

where:
d = deviation of each point.

Thus:

$$\pm d = A + Bx - y$$

and,

$$d^2 = (A + Bx - y)^2$$

The sum of the squares of the deviations is expressed by the equation:

$$\Sigma d^2 = \Sigma(A + Bx - y)^2$$

The value of $\Sigma\, d^2$ may be minimized by setting the partial derivatives with respect to A and B equal to zero. Representing the above functions by f and differentiating:

$$\frac{df}{dA} = 2\Sigma(A + Bx - y) = 0$$

and

$$\frac{df}{dB} = 2\Sigma(A + Bx - y)x = 0$$

Dividing by 2 and summing as directed:

$$\Sigma A + B\Sigma x - \Sigma y = 0$$

$$A\Sigma x + B\Sigma x^2 - \Sigma xy = 0$$

$$\Sigma A = NA$$

where:
N = number of specimens tested.

Substituting and transposing:

$$NA + B\Sigma x = \Sigma y \quad \ldots\ldots\ldots (3)$$

$$A\Sigma x + B\Sigma x^2 = \Sigma xy \quad \ldots\ldots\ldots (4)$$

Substituting the data summarized in Table I in Eqs 3 and 4:

$$33A + 1495.50B = 140.34425$$

$$1495.50A + 68066.717B = 6339.8041$$

Evaluation of the constants A and B gives the equation of minimum deviation:

$$y = 7.39704 - 0.06938x$$

or, since:

$$y = \log S \text{ and } x = P$$

$$\log S = 7.39704 - 0.06938P \ldots (5)$$

To determine the limits of the nominal 95 per cent confidence band, Eq. 5 was used to calculate the values of $\log S'$ (upper limit) and $\log S''$ (lower limit) from the time-temperature data for each test. The difference between these values and the value of $\log S$ used represents the deviation, d, for each test. The standard deviation, σ, is expressed by the equation:

$$\sigma = \sqrt{\frac{\Sigma d^2}{N}}$$

where:
d = deviation of $\log S$ of individual tests from the calculated values, and
N = number of tests.

Substituting these data from Table I gives:

$$\sigma = \sqrt{\frac{0.0324327}{33}} = 0.03135$$

The limits of the nominal 95 per cent confidence band for $N = 33$ specimens are given by a deviation of 1.96 σ above and below the line of minimum deviation. Thus, the nominal 95 per cent confidence lines may be expressed by:

$$\log S \pm 1.96\sigma = A + BP$$

$$\log S \pm 0.0614 = A + BP$$

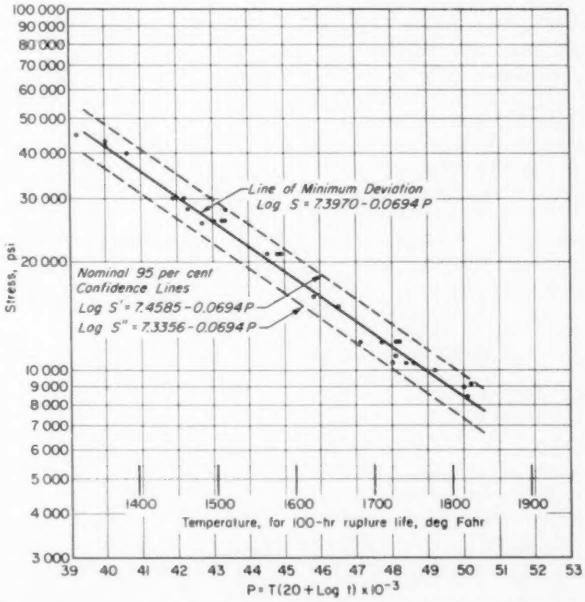

Fig. 1.—Master-rupture graph for Stellite 31 illustrating data that follow a straight-line relation and showing the line of minimum deviation and the nominal 95 per cent confidence band.

TABLE II.—REPRESENTATIVE NICROTUNG DATA FROM A TOTAL OF 85 STRESS-RUPTURE TESTS USED FOR DETERMINING THE LINE OF MINIMUM DEVIATION AND THE 95 PER CENT CONFIDENCE BAND.

Temperature, deg Fahr	Stress, psi	Time, hr	P	x' $(P - 36)^2$	$y = \log S$	$(x')^2$	$x'y$	Log S (Calculated)	Deviation, d	d^2
1500.......	60 000	48.2	42.48	41.9904	4.77815	1763.19369	200.63643	4.76876	+0.00939	0.000088
1700.......	30 000	96.4	47.48	131.7904	4.47712	17368.70955	590.04144	4.49967	−0.02255	0.000509
1800.......	25 000	49.8	49.02	169.5204	4.39794	28737.16602	745.54055	4.38660	+0.01134	0.000129
1900.......	15 000	101.5	51.92	253.4464	4.17609	64235.07767	1058.41498	4.13511	+0.04098	0.001679
2000.......	10 000	40.6	53.17	294.8089	4.00000	86912.28752	1179.23560	4.01117	−0.01117	0.000125
Totals for 85 tests.................				13106.0294	376.76623	2215049.36617	57510.95378			0.110056

$$\log S = A \pm 0.0614 + BP$$

When the above deviation is substituted in Eq 5, the upper and lower limits of the nominal 95 per cent confidence band may be expressed as:

$$\log S' \text{ (the upper limit)} = 7.39704 + 0.0614 - 0.06938P$$

or:

$$\log S' = 7.4585 - 0.06938P \quad \ldots(6)$$

and:

$$\log S'' \text{ (the lower limit)} = 7.39704 - 0.0614 - 0.06938P$$

or:

$$\log S'' = 7.33560 - 0.06938P \quad \ldots(7)$$

Values of P were substituted in Eqs 5, 6, and 7, and the values of S, S' and S'' were calculated. These data are shown in Fig. 1 as the upper and lower limits of the nominal 95 per cent confidence band and the line of minimum deviation. The test data are presented on this graph.

General Discussion of Stellite 31 Analysis

The objective in reporting this method of analyzing stress-rupture data is to present a practical method which can be plotted on a master-rupture graph and used as a guide for design purposes. It is recognized that the methods used are not in strict agreement with standard statistical analysis methods. The points in disagreement with these methods are as follows:

1. The dependent variable, log t in this case, is on the right side of the equation, instead of on the left.
2. The deviations are measured in the direction of the independent variable, log S, instead of in the direction of the dependent variable, log t.
3. The confidence band is of constant width, instead of being narrowest at the centroid of all the data and increasing in width as the distance from the centroid increases.

As shown in Fig. 1 the curves representing the functions presented in this paper represent the experimental data very well in spite of these discrepancies from standard methods of statistical analysis. To further evaluate these functions Mr. H. Ginsburg of the Experimental and Statistical Analysis Dept., Materials Engineering, Westinghouse Electric Corp., was consulted, and he suggested the following equation as representative of the Stellite 31 data:

$$\log t = K_0 + \frac{K_1}{T} + \frac{K_2 \log S}{T} + e$$

where:

t = time, hr,
T = temperature, deg R,
S = stress, psi,
e = deviation of test data from the equation, and
K_0, K_1, and K_2 = constants.

Calculation of the constants in the above equation, using the Stellite 31 data summarized in Table I, gives:

$$\log t = -21.76025 + \frac{114558.67}{T} - \frac{15422.27 \log S}{T}$$

When plotted on the master-rupture graph this equation showed very close agreement with the minimum deviation line in Fig. 1.

Equation 5, $\log S = 7.39704 - 0.06938\,P$, which represents the minimum deviation line for Stellite 31, was converted to a three-variable equation by substituting $T(20 + \log t)\ 10^{-3}$ for P. This equation was then put into the same form as the Ginsburg equation, with the following result:

$$\log t = -20 + \frac{106616.31}{T} - \frac{14413.30 \log S}{T}$$

This equation is considered to be in good agreement with the Ginsburg equation.

The confidence band as presented in this paper appears to be representative of the data studied. It is recognized that a band showing a definite confidence level would become wider as the distance from the centroid of the data increased. The calculation of such a confidence band would become very involved.

Analysis of Stress-Rupture Data That Follow a Parabolic Function

Stress-rupture data for Nicrotung, which was developed by Brown,[3] follows a parabolic function as shown on the master-rupture graph in Fig. 2. A second-degree equation will give the curve that represents these data provided the axis of the parabola is properly located. These objectives were accomplished by using the straight-line equa-

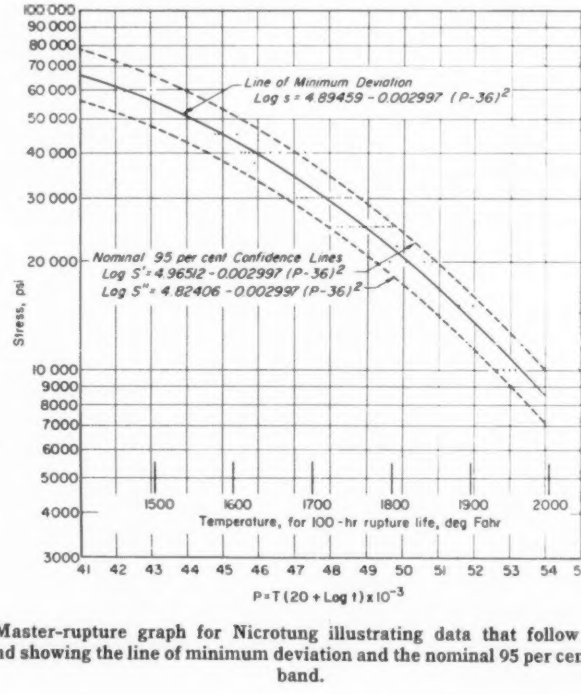

Fig. 2.—Master-rupture graph for Nicrotung illustrating data that follow a parabolic relation and showing the line of minimum deviation and the nominal 95 per cent confidence band.

[3] J. T. Brown, "Two New 1800 F Alloys for Cast Turbine Blades—Nicrotung," *Metal Progress*, Vol. 74, Nov., 1958, pp. 83–87.

TABLE III.—CONVERSION OF STRESS-RUPTURE DATA ON NICROTUNG TO STRESS AT 1700 F FOR 100-HR LIFE TO RUPTURE TO SHOW EFFECTS OF CASTING PROCEDURES.

Heat	Melting and Casting Procedure	Temperature, deg Fahr	Stress, psi	Time, hr	P	$(P-36)^2$	$B(P-36)^2$	Log S	Log S_{17}	S_{17}	Average S_{17}
A...	Melted and cast in vacuum from prime materials	1700	30 000	119.3	47.68	136.42	0.40926	4.47712	4.48963	30 900	
		1700	30 000	96.4	47.48	131.79	0.39537	4.47712	4.47574	29 900	
		1700	30 000	190.2	48.12	146.89	0.44067	4.47712	4.52104	33 200	
		1800	25 000	49.8	49.02	169.52	0.50856	4.39794	4.50975	32 300	
		1800	25 000	34.0	48.67	160.53	0.48159	4.39794	4.48278	30 400	
		1800	25 000	42.4	48.88	165.89	0.49767	4.39794	4.49886	31 500	31 400
B...	Master heat, melted in vacuum, cast under argon, remelt and cast in vacuum	1700	30 000	117.7	47.6	134.56	0.40368	4.47712	4.48405	30 500	
		1700	30 000	260.4	48.4	153.76	0.46128	4.47712	4.54165	34 800	
		1700	30 000	305.5	48.5	156.25	0.46875	4.47712	4.54912	35 400	
		1700	40 000	37.75	45.5	90.25	0.27075	4.60206	4.47606	29 900	
		1700	40 000	79.5	46.2	104.04	0.31212	4.60206	4.51743	32 900	
		1800	25 000	59.5	49.2	174.24	0.52272	4.39794	4.52391	33 400	
		1800	25 000	54.5	49.1	171.61	0.51483	4.39794	4.51602	32 800	
		1800	25 000	99.5	49.7	187.69	0.56307	4.39794	4.56426	36 700	33 300
C...	Master heat, melted in vacuum, cast under argon, remelt and cast under argon	1700	30 000	103.4	47.52	133.71	0.39813	4.47712	4.47850	30 100	
		1700	30 000	134.0	47.77	138.53	0.41559	4.47712	4.49596	31 300	
		1700	30 000	69.0	47.17	124.77	0.37431	4.47712	4.45468	28 500	
		1700	30 000	113.4	47.62	135.02	0.40506	4.47712	4.48543	30 600	
		1800	25 000	42.5	48.86	165.38	0.49614	4.39794	4.49733	31 400	
		1800	25 000	31.85	48.58	158.26	0.47478	4.39794	4.47597	29 900	
		1800	25 000	38.9	48.78	163.33	0.48999	4.39794	4.49118	31 000	
		1800	25 000	35.4	48.68	160.78	0.48234	4.39794	4.48353	30 500	
		1800	25 000	20.2	48.14	147.38	0.44214	4.39794	4.44333	27 800	30 100

tion in which x' represents a second-degree function of the parameter. Thus:

$$y = A + Bx'$$

where:

$y = \log S$,
$x' = (P - K)^2$, and
A and B = constants.

K is a constant which was evaluated by trial to locate the axis of the parabola in agreement with the experimental data. For this alloy and several other heat-resisting alloys, $K = 36$ was found to give good agreement with experimental data. Following the procedure used for the straight-line function, except that $x' = (P - 36)^2$, the constants A and B were evaluated in the following equations:

$$NA + B\Sigma x' = \Sigma y$$

$$A\Sigma x' + B\Sigma(x')^2 = \Sigma x'y$$

Eighty-five specimens of Nicrotung were tested in stress-rupture and used for evaluating the constants A and B in the above equations. Table II shows representative test data and the summation coefficients to illustrate calculations used. Substituting these values in the above equations:

$$85A + 13106.0294B = 376.76623$$

$$13106.0294A + 2{,}215{,}049.366B = 57510.95378$$

Evaluation of the constants A and B gives the following equation for the line of minimum deviation:

$$y = 4.89459 - 0.002997x'$$

By substituting for the values of x' and y, the above becomes

$$\log S = 4.89459 - 0.002997\,(P - 36)^2 \quad \ldots (8)$$

To determine the limits of the nominal 95 per cent confidence band, Eq 8 was used to calculate the values of log S' and log S'' from the time-temperature data for each test. The deviation, d, of each test was determined as the difference between log S and log S' or log S''. The standard deviation, σ, was evaluated from the data summarized in Table II as follows:

$$\sigma = \sqrt{\frac{\Sigma d^2}{N}} = \sqrt{\frac{0.110056}{85}} = 0.03598$$

The upper limit of the nominal 95 per cent confidence band then becomes:

$$\log S' = 4.89459 + 0.03598 \times 1.96 - 0.002997\,(P - 36)^2$$

$$= 4.96512 - 0.002997\,(P - 36)^2 \ldots (9)$$

and the lower limit:

$$\log S'' = 4.89459 - 0.03598 \times 1.96 - 0.002997\,(P - 36)^2$$

$$= 4.82406 - 0.002997\,(P - 36)^2 \ldots (10)$$

Equations 8, 9, and 10 were used to calculate the values of S, S' and S'' for values of P from 40 to 54. These values are plotted on the master-rupture graph presented in Fig. 2.

Application of the Minimum Deviation Function

In Figs. 1 and 2, the values of P are shown for 100-hr rupture life at various temperatures. The average stress and the limits of the nominal 95 per cent confidence band for 100-hr life at a given temperature can thus be read from the graphs. For other values of P the stress can likewise be read from the graph.

The representative stress for any desired time to fracture at a given temperature may be calculated by the above function. For example, it is desired to calculate the average stress for Nicrotung to fracture in 200 hrs at 1800 F. The minimum deviation function will give this average value.

$$\log S = 4.89459 - 0.00300\,(P - 36)^2$$

$$P \text{ for 1800 F and 200 hr} = 50.38$$

$$\log S \text{ for 1800 F and 200 hr} = 4.89459 - 0.00300\,(50.38 - 36)^2$$

$$= 4.89459 - 0.00300 \times 206.7844$$

$$= 4.89459 - 0.62035$$

$$= 4.27424$$

$$S \text{ for 1800 F and 200 hr} = 18{,}800 \text{ psi}$$

Since the data for Nicrotung covered the time-temperature range of 1800 F and 200 hr, this value for stress is fully justified. However, the calculation of the 5000-hr life at 1800 F could not be relied upon without substantiating test data. The calculated stress would serve as a guide for the testing in this range of life and would reduce the number of tests necessary to evaluate the calculated value of S.

A very useful application of the above functions is the conversion of test data to a standard time-temperature condition. Stress-rupture data are normally expressed in three variables (time, stress, and temperature), which makes an evaluation difficult. This is especially noticeable when studying the effects of composition or fabrication variables. Using the minimum deviation equation these data may then be expressed as stress for 100-hr life or any other desired time to rupture at a given temperature. As an example, take the data for three experimental heats of Nicrotung in which the melting and casting conditions were varied. Equation 8 for the minimum deviation for Nicrotung represents the test data:

$$\log S = 4.89459 - 0.00300\,(P - 36)^2 \ldots (8)$$

and the equation

$$\log S_{17} = 4.89459 - 0.00300\,(P_{17} - 36)^2 \ldots (11)$$

represents the stress for 100-hr life to rupture at 1700 F. Subtracting Eq 8 from 11:

$$\log S_{17} - \log S = 0.00300\,(P - 36)^2 - 0.00300\,(P_{17} - 36)^2$$

Substituting the value of P_{17} (100 hr at 1700 F) and transposing:

$$\log S_{17} = \log S + 0.00300 (P - 36)^2 - 0.39675$$

Table III shows stress-rupture data for three heats of Nicrotung prepared under different casting conditions. The calculation of the stress for 100-hr life at 1700 F is also illustrated in this table. These data show good agreement for stress-rupture tests measured at different temperatures and stresses. A comparison between heats prepared under different conditions shows the lowest value of S_{17} for the heat remelted in an arc furnace under argon and the highest value for the heat remelted and cast in vacuum. These heats were remelted master heats that were refined in vacuum and cast under argon. Heat A was melted and cast in vacuum from prime materials and had an average rupture stress at 1700 F and 100-hr life intermediate between heats B and C.

Conclusions

The method of analysis of stress-rupture data presented in this paper has been used by the Westinghouse Aviation Gas Turbine Div. for ten alloys subjected to elevated-temperature applications. The functions and the master-rupture graphs for each alloy represented the test data with excellent agreement. From this experience with the method, the following conclusions are presented:

1. The minimum deviation function more accurately represents the data than a visually drawn curve on the master-rupture graph.
2. The number of tests necessary to evaluate the properties of an alloy are appreciably reduced, since all of the data in three variables are used in deriving the minimum deviation function and the confidence band.
3. The derivation of a representative function in two variables is much simpler than for three variables.
4. The minimum deviation function can be used to convert stress-rupture data to stress for predetermined time-temperature conditions. This facilitates the evaluation of the effects of composition and processing variables.

Creep Testing by Centrifugal-Force Loading

By R. E. HOOK, A. M. ADAIR, and J. W. SPRETNAK

A centrifugal-force-loading creep testing machine was designed, constructed, and tested. Creep data were obtained for electrolytic tough-pitch copper at 300 C and evaluated statistically. Although heat treated and prepared identically, specimens from different as-received rods exhibited a significant variation in creep behavior. This variation in creep behavior was attributed to small differences in metallurgical structure, probably due to prior thermal and mechanical history. Tests on binary nickel-aluminum alloys revealed such significant creep strength differences that considerable scatter of the data for each alloy did not affect the determination of the relative creep strengths.

A CREEP TESTING technique using centrifugal force as the method of loading was developed in 1949 by I. I. Kornilov of Baykov Inst., Moscow (Academy of Sciences, USSR). Specimens can be tested either in tension or bending using this technique. Kornilov used the bending method exclusively for studying the effect of composition on the creep behavior of many alloy systems, including binaries (**1-4**),[1] ternaries (**5, 6**), quaternaries (**7**), quinaries (**8**), and systems of greater than five components (**9**). Data on these systems are usually presented as a plot of composition versus the time required to reach some selected value of bend deflection under isothermal conditions. The maxima of these curves then represent the compositions of maximum heat resistance (creep strength) at given temperatures. It was found to be generally true, based on this type of study on a great many alloy systems, that alloy compositions of maximum creep strength correspond to saturated solid solutions at lower and intermediate temperatures and to more dilute solutions at higher temperatures.

The purpose of this investigation was to determine the statistical dispersion of creep data obtained by the centrifugal method and to determine whether the variation in data obtained by this method limits its usefulness as a screening tool. Information in the literature on the scatter in creep data is very meager. A small amount of tensile creep data is reported for tests on the same steel conducted at the same stress level and temperature, but by a number of different laboratories (**10**). These data were not treated statistically. However, a systematic statistical study of the stress-rupture test has been made by Phillips and Sinnott (**11**). Sully (**12**) states that, "Even in material taken from the same length of rolled bar, creep tests which agree within 50 per cent in minimum creep rate are considered in good agreement for some

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NOTE—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author or authors. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

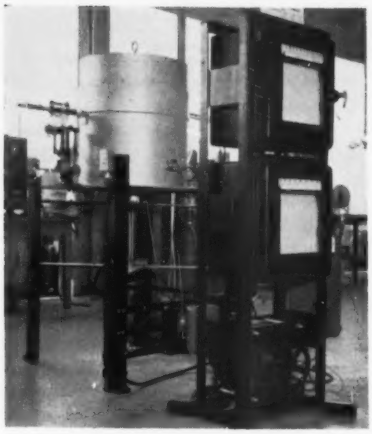


Fig. 1.—Centrifugal-force-loading creep machine.

materials." Harris, et al, (**13**), state that, "The creep strength determined by the tensile method is probably not more accurate than ±5 per cent owing to experimental errors and the inherent scatter present in creep testing." Schulman and Nanis (**14**) report, for high-purity copper wires tested in uniaxial tension at 27 C and 24,200 psi, an average 1-min elongation (15 specimens) of 7.0 per cent and a standard deviation of 1.2 per cent, giving a coefficient of variation of 17.2 per cent.

The results of the present investigation verify that there is a statistical dispersion of creep data for specimens tested under the same conditions. The degree of dispersion depends upon the metallurgical structure.

Description of Equipment

The centrifugal-force-loading creep test machine is illustrated in Figs. 1 to 4. A detailed description has been given previously (**16**). The furnace is operated at 220 v and attains a maximum temperature of 1200 C, and tests can be conducted in an inert atmosphere or in air.

Two Leeds and Northrup Micromax instruments control and record the test temperature. One instrument is used with a control thermocouple in the furnace windings. The other records the testing temperature through a thermocouple in the gas escape tube in the bottom of the atmosphere container. This thermocouple may be pushed against and withdrawn from the bottom side of the specimen holder.

A retaining ring fixed to the specimen holder (Fig. 3) prevents the specimens from deflecting to such an extent that they would strike the wall of the atmosphere container. This ring allows a maximum deflection of 1 in. for a 4-in. long specimen.

Technique of Measuring Creep

Creep deflections were measured by sighting on the tips of the free ends of the cantilever specimens with the cross hairs of a telescope and observing the departure of the specimens from the initially vertical positions. The movements of the free ends of the specimens were measured to the nearest 0.001 in. as indicated by a dial gage actuated by the traversing motion of the telescope. A special flashlight illuminated the specimens.

Deflection measurements could be made only when rotation was stopped. Thus, deflection readings were made at periodic intervals. Creep recovery could, of course, affect the results obtained by using this technique of measurement. However, in these experiments on copper tested at 300 C, no recovery was observed to take place. This finding is in accord with Tietz

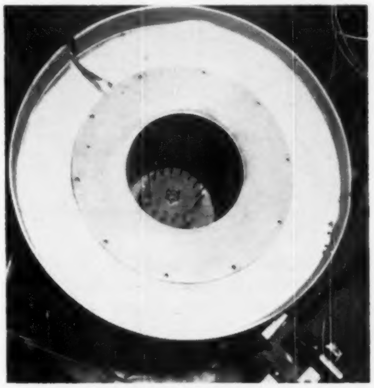


Fig. 2.—Centrifugal machine, top view.

and Dorn (**15**) who found, for oxygen-free, high-conductivity copper creep-loaded in tension at 200 C, that no recovery took place upon removing the load. Their specimen was stored for 1 hr at the test temperature and the load reapplied. The creep curve then continued as if the test had not been interrupted.

This method of deflection measurement eliminates the disparities that might arise if Kornilov's method were used, namely, to stop the machine at certain time intervals and remove the specimens from the furnace, allow them to cool to room temperature, and then make the deflection measurements.

After the specimens were brought to the test temperature and held there for 3 hr, their initial positions were measured and recorded. The specimens were then rotated for 2 sec and the amount of deflection measured. (The full rotational speed is obtained in less than a second.) This deflection was considered to be time-independent plastic yielding and was substracted from all subsequent readings to obtain creep deflection.

Variables Affecting Stress on Specimen

The maximum stress, σ, in the outer fiber of a cantilever beam of circular cross-section loaded by centrifugal force is given by:

$$\sigma = \frac{\pi^2 R L^2 \rho S^2}{450\, gr} \qquad (1)$$

where:

σ = stress in outer fiber, psi,
R = distance from axis of rotation to specimen base, ft,
l = specimen length, in.,
ρ = specimen density, lb per cu in.,
S = speed of rotation, rpm,
g = gravitational acceleration = 32.12 ft per sec,[2] and
r = specimen radius, in.

Since all the variables except S and ρ are geometrical, it is most practical, experimentally, to fix them and write

$$\sigma = K\rho S^2 \qquad (2)$$

where K is a constant.

Thus the maximum outer-fiber stress is proportional to the square of the speed of rotation. The rotational speed is used as the principal means of controlling the initial applied stress. This calculation of σ is based on elastic theory; once plastic deformation occurs the stress distribution will change.

The geometrical variables R, L, and r may vary from specimen to specimen in such a way that some corresponding variation in the calculated value of σ will occur. The effect of variations in the values of R, L, and r on σ was used to determine the tolerances to which the specimens and disk were prepared. The total variation in σ, assuming all variations in R, L, and r are maximum and cumulative, is calculated to be 0.522 per cent.

It is important to note that the maximum fiber stress is directly proportional to the density of the material being tested. This fact is of no consequence if all the specimens tested are of the same material or of materials of the same density. However, if this test method is used to study the creep behavior of various metals and

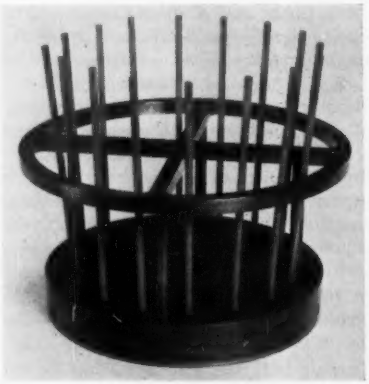


Fig. 3.—Specimen holder, retaining ring, and specimens.

alloys, any variation in density among different specimens must be considered. Suppose one were examining the creep resistance of binary nickel aluminum alloys over a range of aluminum content from 0 to 10 weight per cent. In this case the calculated maximum outer fiber stress would then vary by 19 per cent. To ensure that all the specimens were tested under the same initial stress, some compensation would have to be made for this variation, perhaps, by suitable changes in specimen length, L, since R and r would most likely be fixed by equipment design.

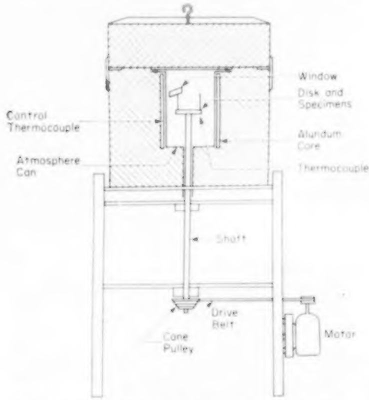


Fig. 4.—Sketch of centrifugal creep machine.

TABLE I.—IDENTIFICATION AND ANNEALING TREATMENTS.

Test	Group (rod)	Number of Specimens	Annealing: Temperature, deg Cent	Annealing: Time, hr
No. 1	A	16	875	8
No. 2	B	16	875	8
No. 3	C	8	875	8
No. 4	D	16	400	1
No. 5	E	16	400	1
No. 6	F	16	400	1
No. 7	G-1	8	400	1
No. 8	G-2	8	400	1

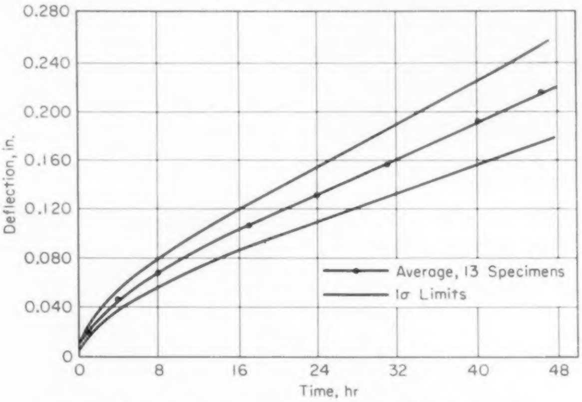


Fig. 5.—Average creep curve and 1σ limits for group A.

Also, changes in the dimensions of R, L, and r due to thermal expansion of the specimen holder and specimens at the various test temperatures would necessitate making a correction to the calculated value of σ. If specimens having markedly different coefficients of thermal expansion are to be tested simultaneously, then this variation should also be compensated for, to ensure the same initial stress for all specimens.

With this method of testing, creep occurs with increasing stress as the amount of bending increases. The net increase in σ is the resultant of an increase in σ due to an effective increase in R and a small decrease in σ due to an effective decrease in the bending moment caused by a decrease in $L/2$ as the bend deflection increases. However, in the process of bending, all specimens pass through the same stress, only at different times. Therefore, specimens of varying creep strength experience the same stresses at like amounts of bend deflection. Thus, the most objective criterion of creep resistance to adopt is the time required to reach a certain selected amount of bend deflection.

Testing Program and Specimen Preparation

Since the most objective strength criterion (the time required to reach some arbitrarily selected value of bend deflection) may necessitate that the scatter of the data be rather small, it was desirable to ascertain what degree of variance might be expected. It is apparent that the specimen grain size might have a significant effect on the variance of the data because of the pronounced stress gradient across a specimen loaded in bending.

Electrolytic tough pitch copper was used for the statistical study. The specimens were centerless ground from $\frac{3}{16}$-in. diam rod to a uniform diameter of 0.1249-in. (+0.0000, −0.0003-in.) and to a length of 4.625-in., (+0.001, −0.000-in.) and to an 8 to 12 microinch rms finish. At least 16 specimens were prepared from the same rod. Following preparation, the specimens were sealed in evacuated capsules.

Table I gives the identification and annealing treatments. The average grain diameter of the specimens annealed at 400 C was 0.0012 in., while that for groups A and C annealed at 875 C was 0.0027 in. The specimens of group B annealed at 875 C showed unusual structures that will be discussed in the presentation of the results.

Sixteen specimens were tested simultaneously in all tests except 3, 7, and 8, in which eight specimens were tested simultaneously. All tests were conducted in a purified helium atmosphere at 300 C and at 750 rpm, or a calculated maximum fiber stress of 5470 psi.

A few Carbonyl nickel and Carbonyl nickel-base alloys containing aluminum were prepared to the same dimensions and specifications as the copper specimens. Tests on these alloys were to demonstrate the effect of scatter of the data on the results and to demonstrate the effectiveness of the centrifugal method as a screening device for distinguishing differences in creep behavior when the prime variable is composition.

The specimens were centerless ground from 0.190-in. diam cold-swaged rods prepared by The General Electric Research Laboratory. After grinding, the specimens were sealed in evacuated tubes and annealed for 1 hr. The annealing temperatures were varied in order to obtain the same average grain diameter of 0.0016 in. in all the alloys.

Experimental Results and Discussion

Shape of the Deformed Specimens

After creep testing, measurements of the specimen's bend profiles were made to the nearest 0.0001 in. using a toolmaker's microscope. The shape of the bent specimens was parabolic, with most of the bending in the first 0.4 in. of length from the fixed end.

Bend profiles were plotted for a number of specimens of various bend deflections. The maximum fiber strains were then computed using measurements of the lengths of the neutral axes and the lengths of the outer fibers obtained from the bend profiles. A neutral-axis length of 0.4 in. was selected as the length over which strain was computed because the bending occurred fairly uniformly over this length. A linear relationship was found between

the bend deflections and the maximum fiber strain. In this investigation, only deflections to a maximum of about 0.400 in. were of interest, corresponding to maximum fiber strains of approximately 1.2 per cent. The accuracy of deflection measurement, 0.001 in., corresponds to a maximum fiber strain of approximately 3×10^{-5}.

Creep Tests on Copper

All tests on copper were conducted at 300 C and at a calculated maximum fiber stress of 5470 psi. Sixteen specimens were tested simultaneously. Following are the test results and the statistical analysis of these results. The statistical quantities used are the standard deviation, σ, and the coefficient of variation, V, calculated for creep deflection values at various times. The coefficient of variation, V, is defined as:

$$V = \frac{\sigma}{\bar{X}} \times 100 \qquad (3)$$

where $\bar{X}$ is the mean creep deflection. The results are presented and discussed in the order of testing indicated in Table I.

Test 1—Group A.—Figure 5 shows the average creep curve and the 1σ limits for 13 of the 16 specimens on which this test was conducted. Creep for three specimens in this group was much greater than the average shown in Fig. 5. Examination of the microstructure of these three specimens revealed considerable intercrystalline cracking at and near the specimen surface in the region of maximum bending. There appeared to be an unusual amount of oxide segregation in the grain boundaries in these regions. Thus these three specimens were disregarded in the statistical calculations.

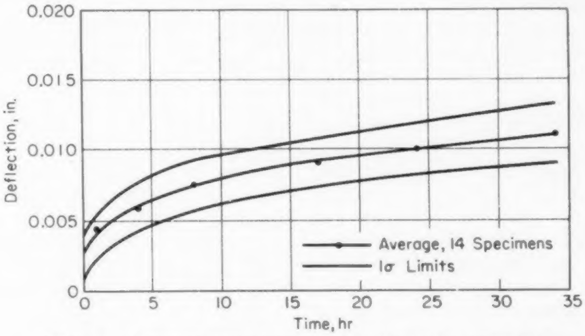
Table II lists 1σ and V as a function of creep time for specimen groups A, B, D, E, and F. For group A, the variation of 1σ with creep time is similar to the variation of bend deflection with creep time. This has the effect that V is nearly constant with time. This behavior of V would be expected if 1σ increases with time at approximately the same rate as the average creep deflection increases with time. The constancy of V with time indicates that there are no inherent metallurgical or experimental factors that tend to affect the scatter of the results. This is somewhat surprising; one might expect the scatter to increase owing to the increase in stress with bending.

In test 3, the eight specimens from group C had the same grain size as group A and gave equivalent creep results.

Test 2—Group B.—Figure 6 shows the creep curve for the average of 14 specimens plus the 1σ limits. Note the change in the deflection scale as compared with Fig. 5. After 24 hr creep these specimens reached an average deflection of 0.010 in. as compared with 0.131 in. for group A.

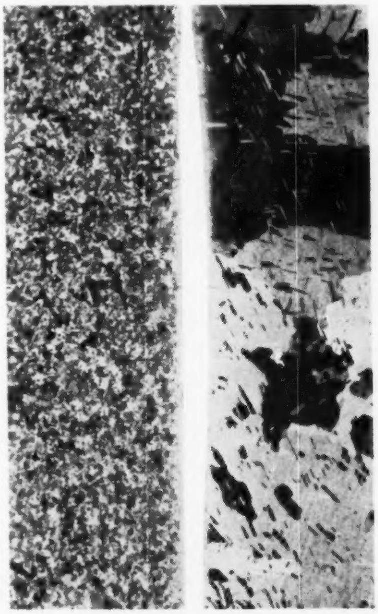
TABLE II.—STATISTICAL DATA ON COPPER.

Creep Time, hr	Group A: 1σ, in.	A: Coefficient of Variation, Per Cent	Group B: 1σ, in.	B: Coefficient of Variation, Per Cent	Group D: 1σ, in.	D: Coefficient of Variation, Per Cent	Group E: 1σ, in.	E: Coefficient of Variation, Per Cent	Group F: 1σ, in.	F: Coefficient of Variation, Per Cent
1	0.0039	19.5	0.0016	37.2	0.0039	6.6	0.0032	6.4	0.0053	7.2
4	0.0071	15.7	0.0017	28.8	0.0055	5.3	0.0054	5.7	0.0087	6.2
8	0.0096	14.1	0.0019	24.6	0.0070	4.9	0.0064	5.0	0.0112	5.9
17	0.0188	17.6	0.0016	17.7	0.0093	4.6	0.0079	4.3	0.0158	5.6
24	0.0226	17.3	0.0020	19.6	0.0109	4.5	0.0087	3.9	0.0179	5.3
31	0.0280	18.0	...	...	0.0131	4.7	0.0097	3.8	0.0204	5.2
40	0.0362	19.0	...	...	...	...	0.0110	3.8	0.0237	5.2
46.3	0.0400	18.7	...	...	...	...	...	...	...	...
48	...	...	...	...	...	...	0.0124	3.9	0.0267	5.2



Figs. 6.—Average creep curve and 1σ limits for group B.

Figure 7 shows two photomacrographs of the longitudinal section of the region of maximum bending for one specimen selected from group A and one from group B. Both specimens were given identical annealing treatments; however, they were prepared from different as-received rods. Oxygen greatly inhibits grain growth in copper (**17**); and, conversely, absence of oxygen allows the grains to grow to a considerable size. An oxygen analysis on specimens of the as-received rods, A and B, showed that specimen A contained 0.029 weight per cent oxygen and specimen B contained 0.013 weight per cent oxygen. Thus, excessive grain growth occurred upon annealing the specimens taken from rod B.



(*a*) Group A. (*b*) Group B.

Fig. 7.—Photomacrographs of section of maximum bending (× 11). Reduced one third in reproduction.

In Table II, the B-group of specimens shows the greatest variation of V with creep time. Since this group deflected to average values of only 0.010 in., it is felt that errors in the measurement of creep deflection were compounded in the calculations and were responsible for this variation in V. It must be remembered that the creep deflection could be measured to the nearest 0.001 in. Hence, gross errors can result in the computation of the average deflection $\bar{X}$, of 1σ, and of V.

From the results of tests 1, 2, and 3 it is concluded that the grain size of the specimens plays a significant role in the creep behavior of copper at 300 C using the centrifugal method of testing. Since the large-grain specimens exhibit a greater resistance to creep than the smaller-grain specimens, it may be assumed that for these test conditions the specimens were above the equicohesive point. A study of the tensile creep behavior of high-purity copper by Car-

reker and Guard (**18**) showed that at 300 C larger-grain-size specimens were more creep resistant than finer-grain-size specimens.

From the foregoing results it was suspected that perhaps a large part of the scatter in the data could be attributed to grain size and to subtle variations in the grain-size distribution from specimen to specimen. When reference is made to the variation of grain-size distribution, it is necessary to keep in mind the possible associated distribution of grain orientations or texture. It must be recalled that in these experiments creep is occurring in bending of specimens $\frac{1}{8}$ in. in diam. This means that the elastic fiber stress varies linearly from a maximum of 5470 psi at the specimen surface at the fixed end to zero at the neutral axis over a specimen radius of $\frac{1}{16}$ in. For a uniform grain diameter of 0.0025 in., a drop in stress of 220 psi would occur across each grain. It seems reasonable, then, that the grains at and near the specimen surface control to a considerable degree the creep behavior. Thus chance variations in grain size and grain orientation could account, to a large degree, for the scatter in the creep data. The situation may be somewhat analogous to the scatter encountered in fatigue, which is of considerable magnitude and may be ascribed to chance variations in the degree of fatigue damage in various local regions of a specimen. Average properties are not measured in fatigue, but it is a weakest-link phenomenon subject to chance variations.

By testing specimens smaller in grain size than those of group A, a reduction in the scatter would be expected through increasing the number of grains primarily controlling the creep behavior and averaging out to a greater extent any orientation effects. To test this supposition, three groups of 16 specimens each were prepared. Each group was taken from a different as-received rod of copper. These groups are designated D, E, and F, and their annealing treatment is indicated in Table I. The creep curves and statistical data are shown in Fig. 8 and Table II, respectively. As can be seen from the data, there is a considerable reduction in the scatter compared with test 1, group A. The coefficient of variation has been reduced by a factor of approximately 3.5 to 4.

It was anticipated that the results of tests on groups D, E, and F should not be significantly different, and thus the data could be used collectively for statistical calculations. However, such is not the case, as can be seen in Fig. 8. The t test for significance indicates that there is a significant difference between the average creep curves of groups D and E, and there is an obviously significant difference between the averages of F and D, and F and E.

The difference in creep behavior of these three groups must be ascribed either to an inability to reproduce the test conditions with a sufficient degree of accuracy, or to the existence of definite metallurgical differences among the three groups of specimens, or both.

To show that the results can be reproducible, two test runs were made on eight specimens each. In this case all the specimens were taken from the same as-received rod. The tests are designated as: test 7—group G-1; and test 8—group G-2. The average creep curves for G-1 and G-2 are shown in Fig. 9. Table III gives the results of statistical calculations for these data. The F and t tests for significance show that there is no significant difference between either the variance of the data or

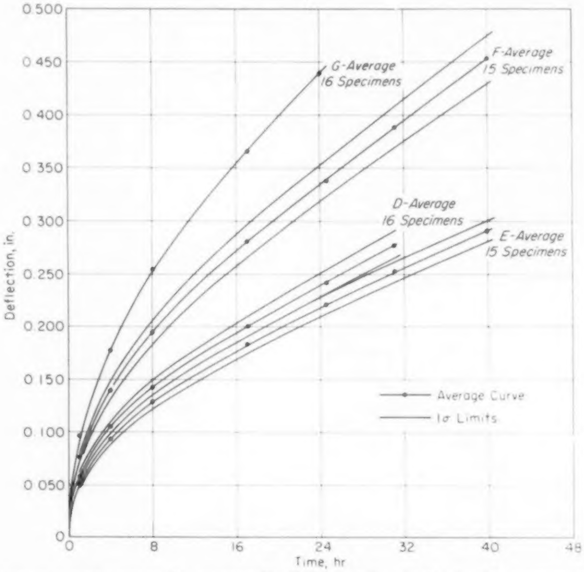


Fig. 8.—Average creep curves for groups D, E, F and G; 1σ limits for groups D, E, and F.

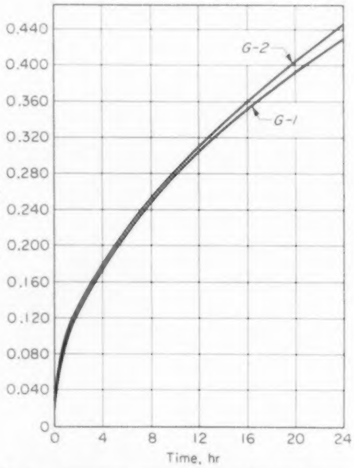


Fig. 9.—Average creep curves for two tests—8 specimens per test.

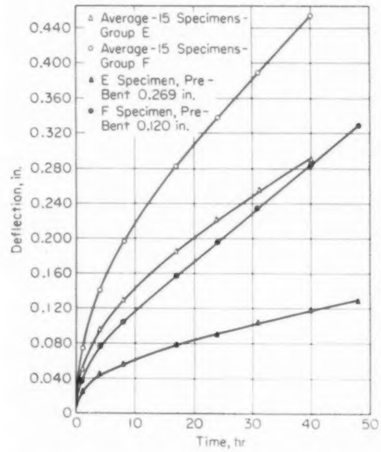


Fig. 10.—Effect of pre-strain on creep behavior.

TABLE III.—CREEP DATA AND STATISTICAL RESULTS FOR TEST 7—GROUP G-1 AND TEST 8—GROUP G-2.

Time	Average Deflection, in.		1σ		Coefficient of Variation, Per Cent		F (0.995 confidence level)	t (0.995 confidence level)
	G-1	G-2	G-1	G-2	G-1	G-2		
2 sec.	0.042	0.043	0.0057	0.0063	13.5	14.7	NSD[a]	NSD[a]
1 hr.	0.099	0.094	0.0092	0.0080	9.3	8.5	NSD[a]	NSD[a]
4 hr.	0.178	0.175	0.0140	0.0127	7.9	7.3	NSD[a]	NSD[a]
8 hr.	0.248	0.262	0.0147	0.0169	5.9	6.7	NSD[a]	NSD[a]
17 hr.	0.363	0.371	0.0220	0.0234	6.1	6.3	NSD[a]	NSD[a]
24 hr.	0.431	0.453	0.0261	0.0260	6.0	5.8	NSD[a]	NSD[a]

[a] No significant difference.

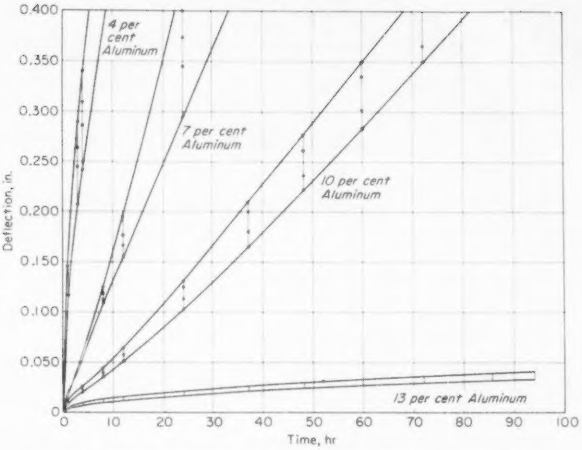


Fig. 11.—Creep behavior of nickel-aluminum alloys at 650 C.

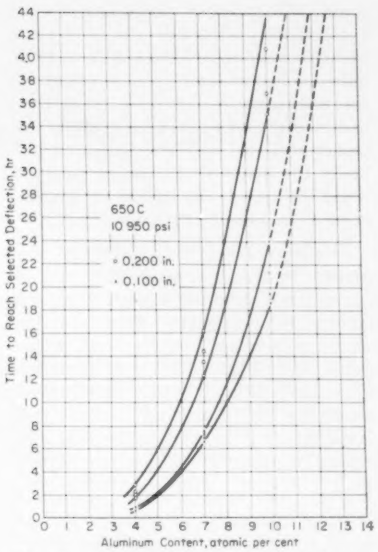


Fig. 12.—Composition—creep resistance diagram, nickel-aluminum.

between the means for these two tests conducted on specimens taken from the same rod of copper.

The metallurgical difference that could produce such significantly different creep behavior of groups D, E, F, and now G, could be attributed to either composition differences or differences in prior thermal-mechanical history, or both. Although these groups represent different rods of copper, they were all given the same annealing treatment prior to creep testing, and there were no observable differences in grain size.

The electrical resistivity, which would have given an indication of compositional differences, was measured for annealed specimens from groups E, F, and G. However, no differences were observed. There remains the possibility of a thermal-mechanical history difference to which the difference in creep behavior may be attributed. There is no doubt that such a difference can exert a considerable influence on creep behavior. This is particularly evident in this type of creep test and is demonstrated in Fig. 10. When the statistical results were reported on groups E and F, only 15 specimens were considered. This is because one specimen in each group was pre-bent and straightened at room temperature prior to testing. The amounts of pre-strain are given in Fig. 10. This small pre-strain significantly altered the resulting creep behavior of these specimens. As seen from creep curves, the specimen of group E, which was given the greater pre-strain, was strengthened more than the specimen of group F, which was given the smaller pre-strain.

The diamond pyramid hardness was measured on specimens from groups E, F, and G. A larger number of values were obtained and treated statistically with the result that a small but significantly different hardness increase corresponds to an increase in creep resistance from G to F to E. In order to further establish a difference among these groups of specimens, they were investigated by X-ray diffraction. Marked differences were found in texture along with small differences in line broadening, indicating that metallurgical differences did exist among the three groups.

Creep Tests of Nickel-Rich, Aluminum Binary Alloys

This test was conducted at 650 C in air at a rotational speed of 1080 rpm giving a calculated maximum fiber stress of 10,950 psi. The creep curves for four specimens each of compositions 4, 7, 10, and 13 atomic per cent aluminum are shown in Fig. 11. Specimens of pure nickel and alloys of 1 and 2 atomic per cent aluminum tested previously at the same rotational speed and at a temperature of 600 C deflected to the maximum extent in such a short time that these compositions were not incorporated in the test reported here.

These data illustrate the usefulness of the centrifugal method as a screening tool. It is relatively simple to take a number of alloys and readily determine which compositions exhibit the greatest resistance to creep for the same conditions of stress and temperature.

The relative strength criterion (the time required to reach some selected value of bend deflection) for a number of alloys is implemented by drawing a line through the selected deflection parallel to the axis along which creep time is plotted. The intersections of this line with the creep curves then determine the times at which each alloy has reached this selected deflection value. The value or values of deflection would be selected so that the line drawn through the creep curves intersects the greatest possible number of them in the range of secondary creep.

If there are large differences between the creep behavior of the alloys tested, then one would expect the effect of scatter of the creep data or the time criterion for relative strength to be minimized. However, if the differences in creep behavior are small so that the scatter bands overlap, one would be unable to distinguish strength differences with certainty, especially if only one or two specimens of each composition were tested.

The strengths of the nickel alloys (Fig. 11) are so different that the range of the data for any alloy does not overlap the range for any other alloy. No alteration in the specimen geometry was made for the different alloys to equalize the initial calculated maximum fiber stresses. Thus this stress was some 8 per cent less for the 13 per cent aluminum alloy than for the 4 per cent aluminum alloy. However, the creep strengths for these alloys are so markedly different that this stress difference could account for only a negligible fraction of the difference.

The creep curves shown in Fig. 11 were used to construct curves of time required to reach bend deflections of 0.100 and 0.200 in., as shown in Fig. 12. The 13 per cent aluminum alloy did not reach the least of these deflections in the test period, which was 94 hr. In this case, the scatter of the data has little effect on one's ability to ascertain the relative strengths of these alloys.

Conclusions

From the results of this investigation, the following specific conclusions are reached:

1. The centrifugal-force loading method of creep testing in cantilever bending is quite suitable for use as a screening tool. With it, one can readily and inexpensively evaluate the relative strengths of alloys of various composition or of metals and alloys for which

some primary factor affecting creep has been varied. Absolute values of creep strength cannot be obtained from these data. The inherent disadvantage of this testing method, namely, an increase in the load as deformation increases, together with an inability to define precisely the creep stress and strain, preclude the use of this testing method for other than a screening tool.

2. There is a certain degree of dispersion in the creep data gathered by this method in which a large number of specimens are tested simultaneously under the same conditions of initial stress and temperature. This dispersion must arise predominantly from variations in metallurgical structure introduced by differences in processing within the limits of commercial practice.

3. In order to minimize the dispersion of creep data gathered by the centrifugal method in bending, the number of grains per cross-sectional area of specimen should be maximized. Prior mechanical and thermal history should also be known and closely controlled.

4. Relatively large amounts of dispersion can be tolerated without seriously affecting the interpretation of relative strength differences, when the strength differences among the specimens are large.

Acknowledgments:

The authors gratefully acknowledge the helpful discussions with H. A. Lipsitt, L. R. Bidwell, and H. J. Garrett concerning the statistical analysis, the design of the experimental equipment, and the X-ray diffraction data.

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Gerard Troost

(1776–1813)

BORN IN Holland, Gerard Troost became an eminent crystallographer and geologist. As geologist for the State of Tennessee, he prepared an elaborate report on the iron resources of that state. The constituent of steel called "troostite" was named after him by the noted French metallurgist Floris Osmond. Troost was founder and first president of the Philadelphia Academy of Natural Sciences.

This is one of a series of photographs from a collection compiled by Prof. Jasper O. Draffin and displayed in the Arthur N. Talbot Laboratory, University of Illinois.

Use of the Bulge Test for Determining Mechanical Properties of Stainless Steel Foil

By D. B. BALLARD

A hydraulic bulge tester for foil was assembled from commercially available high-pressure equipment. The mechanical properties determined were yield pressure, burst pressure, and maximum bulge height. The change in yield pressure was found to be a sensitive measure of the effect of different heat treatments on precipitation-hardening stainless steel foil. The test was easily conducted and had several advantages over the tension test for use on high-strength foils.

IN METALLURGICAL investigations that involve heat treatment, there is an important advantage to the use of material in the form of foil. Owing to the large surface-to-volume ratio, the material reaches the temperature of its surroundings rapidly, even in vacuum. This fact led to the decision to use foil specimens for much of the work in a current investigation of the reactions occurring in precipitation-hardening stainless steels. The commercial availability of several of these materials in foil form made it easy to obtain a very large number of specimens from a single piece of steel, virtually eliminating uncertainties due to variation in composition from one specimen to another.

The principal disadvantage connected with this procedure was the lack of a convenient way to determine the mechanical properties of the foil resulting from various treatments. Conventional hardness tests are impossible, microhardness tests require mounting and polishing of specimens, which are difficult and time consuming, and tension tests require very careful specimen preparation to avoid misleading results. Therefore, there was a need for a reliable test to determine mechanical properties of this type of material; preferably such a test should be inexpensive and easy to conduct, and should require only a small amount of material. The hydraulic bulge test has been found to meet these requirements very satisfactorily.

A number of investigators have used a diaphragm loaded by fluid pressure to study the properties of materials, (**1–6**).[1] The principal objective of these tests was to determine the degree of formability of the material, the test values which were usually recorded being pressure and bulge height at rupture. The height of bulge was measured by various methods, several of which are described in the literature (**1**, **2**, **4**, **5**, **10**, **12**). Other investigators have been primarily concerned with the stress-strain relationship under the applied biaxial stress as the material deforms (**5**, **7–11**). Several modifications of the formulas that correlate the stress-strain relationship as applied to the diaphragm test have been studied, and it has been reported, among other conclusions, that it is not possible to determine the linear plastic strain by measurement of bulge height alone. Several investigators have used other methods, such as measurement of the shape of the bulge as the height increased, to make this determination (**4**, **9–12**). However, the hydraulic bulge test has inherent advantages for testing thin foils whose mechanical properties are very sensitive to stress concentrations resulting from nicks, scratches, dents, corrosion, etc.

Specimen Preparation

The specimen preparation for the bulge test was relatively simple. Narrow strips of foil approximately 1 in. wide were sheared from the solution-annealed stainless steel coil. Prior to heat treatment these strips were inspected, and those with scatches, dents, or dark stains were rejected. After heat treatment, disks 0.72 in. in diameter were punched from strips using a specially constructed punch. In order to prevent burring at the edges, the specified maximum clearance between the punch and anvil was 0.0005 in. The next step was to compare the weight of each disk against that of a specimen punched prior to heat treatment. No disk was tested if its weight differed from the comparison specimen by more than 1 mg; this avoided significant differences in thickness of specimens of any one material.

Apparatus and Testing Procedure

Specimens were tested in the apparatus shown schematically in Fig. 1. To prevent fingerprint corrosion, the specimen was placed in the holder (a high-pressure rupture disk holder) by the use of a plastic hose attached to a vacuum service line. A hardened steel hold-down ring with a smooth internal edge radius of 0.02 in. was placed on top of the specimen, and the threaded bushing was screwed down to produce an oil-tight seal. The coarse grinding marks on the flat surface of the hold-down ring, the concentric tool marks on the bearing surface inside the specimen holder, and a high torque applied to the threaded bushing gave sufficient restraint to prevent the specimen from pulling out at the clamped edge. The working or unsupported diameter of the

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

specimen was approximately 0.533 in.

The bulge height indicator, contained in the threaded bushing, consisted of a thin-wall stainless steel tube with a short length of plastic tubing fitted over each end. One end of this assembly rested on the center of the specimen, and the other end was scribed with an index mark. The vertical movement of the indicator was guided by a piece of glass capillary tubing which was held in place by rubber stoppers inserted in both ends of the threaded bushing. The total weight of the indicator assembly was 1.7 g; therefore, its effect on the stress in the sample was negligible. The displacement of the index mark was measured to 0.0001 in. by the use of a cathetometer.

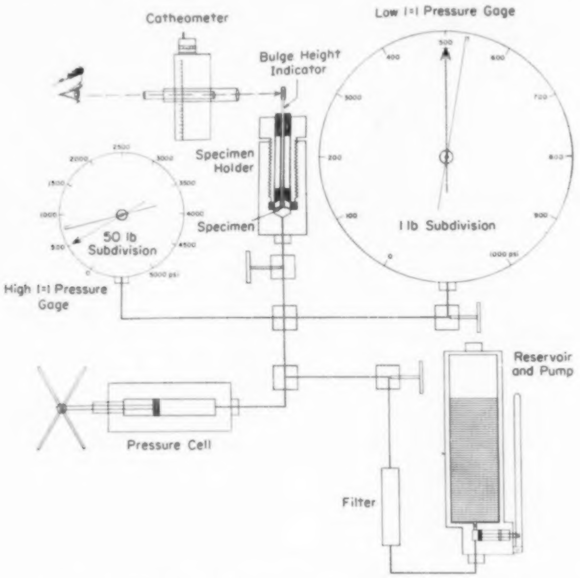
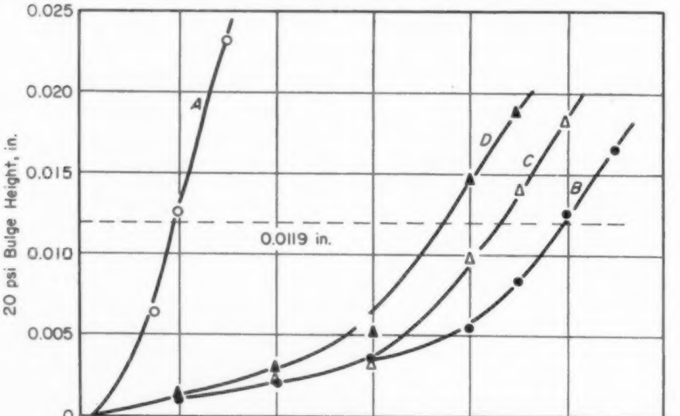


Fig. 1. —Schematic diagram of bulge test apparatus.



Specimens heat treated for conditions A, B, C, and D as listed in Table I. Points are the average of five specimens of each heat treatment. The set was measured after reducing the pressure to 20 psi. The criterion for yield pressure is indicated by the dashed line.

Fig. 2. —Pressure versus permanent set curves for 17-7 PH steel.

TABLE I.—RESULTS OF BULGE TESTS ON 17-7 PH STAINLESS STEEL 0.0028-IN. FOIL.
(Each value is the average of five tests.)

Code	Heat Treatment[a]	Yield Pressure,[b] psi	Burst Pressure, psi	Maximum Bulge Height, in.
A	Solution-annealed	193	2613	0.1556
B	1400 F, 1½ hr 1050 F, ½ hr	993	2750	0.0751
C	1400 F, 1½ hr 1050 F, 1½ hr	865	2637	0.1022
D	1400 F, 1½ hr 1050 F, 6 hr	746	2500	0.1084

[a] All specimens were initially in the solution-annealed condition.
[b] Pressure required to produce a permanent bulge height of 0.0119 in.

The hydraulic fluid was a low-viscosity aircraft instrument oil which was carefully filtered to remove foreign particles. Used oil was removed from the specimen holder after each test to prevent contamination. Connections between all parts of the apparatus were made with 0.020-in. inside diameter stainless steel tubing. This was small enough to prevent damage to the gage by the rapid pressure drop when the specimen burst.

In order to eliminate any slight waviness in the specimen, an initial pressure of 20 psi was applied by turning the handle on the pressure cell, which had previously been filled from the reservoir and hand pump. This slight pressure gave a reproducible position which was used as a zero point for measurement of specimen deflection.

It was desirable to make determinations in the bulge test that would give information on yield strength, and ductility. The bulge height at failure was considered to be an adequate measure of the latter property, but the conditions for measurement of yield pressure had to be decided arbitrarily. Because of the nonlinearity of the pressure-deflection curve, an offset method of determining the yield pressure was considered unreliable, so it was determined from a curve of permanent set as a function of prior pressure. For the sake of consistency, it would have been desirable to choose a yield criterion such that the plastic octahedral shear strain would be the same as that corresponding to 0.2 per cent plastic strain in a uniaxial test. Because of the difficulty of relating bulge height to plastic strain, and particularly the difficulty of evaluating the effect of spring-back stresses, it was not considered possible to determine such a criterion accurately. Consequently it was chosen arbitrarily as a bulge height h, such that $h^2 = D^2/2000$ where D is the unsupported diameter of the specimen. The octahedral shear strain resulting from this much permanent set is probably of the same order of magnitude as that caused by 0.2 per cent offset in a uniaxial stress test.

This procedure required that the pressure be increased in steps during the early part of the test, with readings of bulge height being taken at 20 psi after each increment until the permanent set exceeded the yield value, 0.0119 in. In order to obtain adequate sensitivity, yield pressures were measured with the high-precision, 1000-psi gate. After the yield pressure was reached the valve leading to this gage was closed. Then the pressure was

TABLE II.—DATA FOR SPECIMENS SHOWN IN FIG. 3.

Specimen	Material	Thickness, in.	Heat Treatment	Burst Pressure, psi	Maximum Bulge Height, in.
No. 1	17-7 PH	0.0028	Solution-annealed	2610	0.1536
No. 2	17-7 PH	0.0028	1400 F, 1½ hr 1050 F, 15 min	2725	0.0851
No. 3	AM 350	0.0016	Solution-annealed	1875	0.1295
No. 4	AM 350	0.0016	1710 F, 1 min	1830	0.1305

slowly and continuously increased until the specimen burst. The burst pressure was determined with the 5000-psi gage. The increase of bulge height was followed with the cathetometer in order to determine the maximum deflection just prior to rupture. The failed specimen was easily removed with a small magnet for inspection of the fracture.

Test Results

Figure 2 shows curves of permanent set (in terms of the bulge height after release of load) as a function of applied pressure for 17-7 PH foil in different heat-treated conditions listed in Table I. It can be seen that the yield pressure is a very sensitive measure of the effect of heat treatment and that the maximum bulge height indicates the expected changes in ductility. There is little change in burst pressure as affected by heat treatment, because the nominal bursting strength is a function of both pressure and bulge radius. For foils, the radius at the top of the bulge decreases with increasing bulge height. Therefore the pressure required to fracture a ductile material was higher than that for a brittle material of the same tensile strength. No attempt was made to calculate the tensile strength values because of the uncertainties involved in estimating true radius on the height of bulge alone.

The typical fractures of specimens of 17-7 PH and AM 350 stainless steel foil shown in Fig. 3 and described in Table II indicate that the failures started at the center of the specimen where the material had not been affected by the specimen preparation. In the case of very brittle materials (such as those that had been nitrided) a few specimens broke initially at the hold-down ring at a deflection value much less than that of the specimens that broke normally. Even the most brittle samples tested had sufficient ductility to permit the determination of yield pressure.

The primary use of the bulge test in this investigation has been to evaluate the effect of heat treatments and to correlate mechanical properties with observed changes in structure. Consequently, the results have been used for comparison only, and they have not generally been evaluated in terms of the actual stresses at the yield or the actual

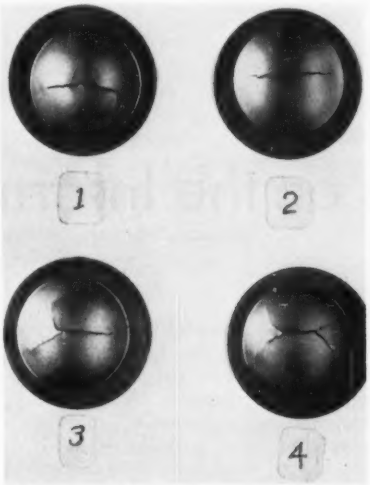


Fig. 3. —Typical burst fractures of thin stainless steel foil.

strains at failure. It appears that the linear plastic strain at failure is larger than that found in tension tests of the same material, which may be an indication of the beneficial effect of testing material away from the edge.

Conclusions

The hydraulic bulge test has been found to be very useful for evaluating the changes in yield strength and ductility due to heat treatment of high-strength foils. Its principal advantages in comparison with the tension test are: absence of edge effects, the small amount of material used, and the simplicity of specimen preparation. All parts of the equipment except the very simple bulge height indicator were stock items available from commercial firms.

The principal disadvantage of this test is the uncertainty in the determination of true stress and strain values, but this is not important for comparison of materials or heat treatments.

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(8) W. F. Brown and G. Sachs, "Strength and Failure Characteristics of Thin Circular Membranes," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 20, No. 3, p. 241 (1948).

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(12) H. J. Read and T. J. Whalen, "The Ductility of Plated Coatings," *Proceedings*, Am. Electroplaters Soc., p. 318, 1959.

". . . a year ago there was some question as to whether or not we are in a space race. We now know that we *are* in a space race and that it is likely to be a fairly long one. We are not racing purely for science. We are racing to demonstrate that we are a successful and dynamic society. We are racing for the prestige necessary in a purely economic world-market situation. We are racing as one method of channeling our excess energy and productivity and for such side benefits as may result. We are racing to demonstrate that democracy is every bit as good if not far superior to communism. And, at times, we are racing out of the sheer joy and exuberance that long have been characteristic of a proud people engaged in a pursuit of happiness." Eberhardt Rechtin, "Why the Space Race?" *Vectors* (Published by Hughes Aircraft Co.), Vol. 2, No. 4, 1960.

MR&S FEATURE

Some Thoughts on the Information Problem

By JOHN C. COSTELLO, JR.[1]

Philosophers have eternally sought to define knowledge. No more nebulous concept exists; none is more difficult to define. Still, we all *think* we know what the concept implies; we each have our own viewpoint and interpretation.

What Is Information?

The *information* in information storage and retrieval can be adequately understood only if the relationship of information to knowledge is understood. As a point of departure, then, let us examine several definitions of knowledge from standard reference works:

- All that the mind knows, from whatever source or by whatever process it is derived, obtained, or acquired
- An organized system of facts
- The comprehension or understanding which follows after the mental acquisition and organization of a body of facts
- The act or state of understanding, that is, a clear perception of the truth, a familiarity gained by actual experience
- That which is known or may be known by a person
- That which is known or may be known by a group of persons, such as an organization or a profession
- That which is known or may be known by the whole of mankind
- The aggregate of facts, truths, or principles possessed by an individual, a group of individuals, an organization, a profession, or by civilization as the sum total of all individuals, organizations, and professions
- The intuitions native to the mind and all that has been learned respecting phenomena, causes, laws, principles, literature, history, etc.

Information is knowledge being communicated. Information applies to facts or ideas which are spoken, written, or otherwise transmitted from sender to receiver. The information may comprise unorganized or even unrelated facts or ideas. An individual, organization, or profession gains knowledge from the information as it is assimilated into meaningful, organized relationships.

Communications Path Is Tortuous

So that knowledge may be communicated, it is usually preserved in some form of a permanent, reusable record. However, knowledge may be communicated without the generation of a record, as when one individual speaks directly to another. In a conversation between X and Y, X is transmitting from his store of knowledge to Y; X furnishes information to Y directly. Direct oral communication of knowledge is a *dynamic* process of information. If the communication of knowledge is accomplished by a written record, it is a *static* or *passive* process of information. In a simple type of static information process, X writes to Y. This is an indirect transmission from X to Y of items from his store of knowledge. When communication *by record* is introduced, serious problems may and usually do arise. Y, not being in the presence of X at the time he receives the information, is unable to ask X to explain the meanings and shadings of meaning of his words. Y must either attribute to X's words his own meanings or he must communicate in written form with X and negotiate the meanings of words until the recorded information is clearly defined so that it may be assimilated and become knowledge.

In today's complex civilization with its rapidly expanding technology, there are many X's working in highly specialized fields. Generally they are individual workers, for all practical purposes completely isolated from others working in the same or related fields with whom they might communicate directly, as in conversation. These individual workers are generating knowledge. The only practical means of transmitting this knowledge from their minds to the minds of others is by static information in the form of written records. The great majority of scientific and technical records are created without the authors' knowing who the addressees may be. The addressees, or receivers of information, may be widely separated from the originators, not only by geography but also by time, language, or culture. Thus communication in intellectual pursuits is usually not only static, but it is also *indirect* and *delayed.*

These records of information are generally in written form—in books, professional journals, periodicals, or such controlled-circulation documents as internal reports. Some other media for static communication of information are design drawings, maps, graphs, charts, and tape or film recordings.

Problem: How To Close the Gap

Regardless of the form of the record, the big problem in the static communication of information is how to close the gap, how to provide for delivery of information to an individual when it is time for him to become an addressee or receiver of anonymously directed records. How can we "bridge the gap" between the individual who seeks information, not knowing where, when, or by whom it may have been recorded, and records created by individuals who did not know where, when, or by whom the information would be needed?

The recognition of the need for a means whereby information recorded by a possessor of knowledge may be

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obtained for reuse by someone who needs that knowledge has resulted in the development in recent years of the art or science known as *documentation*, or, more simply, *information storage and retrieval*. Those engaged in this art or science are known as documentalists, information scientists, or information specialists. Definitions of "documentation" and "information storage and retrieval" vary greatly as the interests of the documentalists, information scientists, or information specialists vary. Our scope of consideration will be limited to those problems which arise from the time documents are acquired by an organization until they are delivered into the hands of the individuals in that organization who need the information they contain.

In this limited scope, information storage and retrieval may be defined as the systematic methods and procedures whereby the information contained in documents, as they become part of an organization's collection, is tagged, identified, or characterized so that it may be located efficiently, rapidly, and inexpensively when it is needed. Efficiency in these systems is related, not only to the amount of pertinent information retrieved, but also inversely to the amount of nonpertinent information that appears in the output. Defined in another way, information storage and retrieval is the handling and processing necessary to complete the transmission from recorder to receiver. It includes all the steps that are taken to close the gaps inherent in the "delayed communication" of indirect, passive, or static information.

Information storage and retrieval in an organization is mobilization of information so that the members of the organization will engage in an absolute minimum of unintentionally duplicated work. In instances where it is decided that work shall be repeated, the information system should provide a complete record of similar or comparable work completed earlier so that the current effort may be undertaken at a higher plateau. The ultimate objective of the system should be to make possible the most effective use of manpower and money by minimizing repetition of work satisfactorily completed at an earlier time.

Information storage and retrieval techniques can be economically justified in any discipline that has its own body of reusable information. For example, for students of the Bible or of literature, information systems may provide concordances of the Old Testament or Shakespeare. Most applications, however, are found in the sciences, technologies, and in business and commerce. Here, information systems may include documents such as internally generated research reports, customer contact reports, patents, articles in professional journals, correspondence, design drawings, process flow sheets, equipment specifications, personnel records, materials specifications, intelligence on competitors' products, analytical data, or medical or criminal case histories.

Two Kinds of Information

To date, there has been inadequate recognition of the fact that there are two distinct types of information in storage and retrieval systems, which I shall label, for lack of better terms, data and descriptive information.[2] A black-and-white differentiation between the two is practically impossible. However, data generally are numerical, that is, quantified or quantifiable, and highly repetitive. Descriptive information, on the other hand, usually is not highly repetitive or quantified or quantifiable but is characteristically narrative, subjective, or qualitative. A narrative record of how a certain experiment was conducted, of the conditions under which it was conducted, and a subjective evaluation of the results obtained are examples of descriptive information. Data concerning the experiment, however, may be in tabular form, listing numerical facts concerning concentrations, dosages, electrical charges, levels of radiation, etc. Obviously, data and and descriptive information require different treatment in storage and retrieval.

Levels of Sophistication

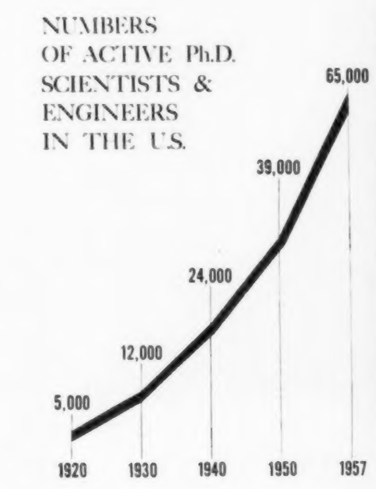
Let us now examine four possible levels of sophication for an information system.

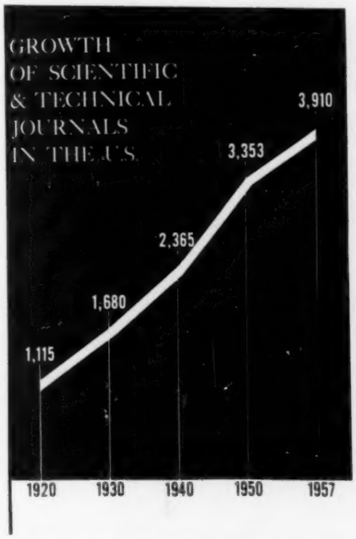
Document Storage

The most common type of system is not one that stores or retrieves the information itself. Rather, what is commonly referred to as an information system stores and retrieves the locations or addresses of sources of the information. A typical example of this is the standard library card catalog. This catalog or index does not provide the desired information directly but does provide identifying numbers of references which direct searchers to locations of those references. This type of system provides a service which should properly be referred to as "document storage and retrieval." They are the simplest systems, those which operate at the lowest level of sophistication and at the least cost. They provide the most effective service per dollar of investment and operating cost.

Information Storage

A system can properly be called an information storage and retrieval system only if the material stored is the actual information itself. This type of system goes one big step beyond the document storage and retrieval type in that when a question is asked the





Shown above are two reasons why we are suddenly faced with an "information problem." This illustration is taken from "Information for Scientists," *NSF-58-34*, published in November, 1958, by the National Science Foundation. Information bringing these curves up to date is no doubt available somewhere, but *MR&S* was unable to retrieve it.

[2] Editor's Note.—Roughly the same kind of distinction has been described by G. S. Simpson, Jr., and J. W. Murdock in "Qualitative Approach to Scientific Information Problems," *Battelle Technical Review*, November, 1960. In that article, Simpson and Murdock state that "information, when put to use, naturally tends to group itself into (1) data and (2) interpretive presentations."

In his 1961 Priestley Medal Address ("Choice and Chance in Scientific Communication," *Chemical & Engineering News*, April 10, 1961), Louis P. Hammett distinguishes between "what I shall call fact information and idea information."

searcher gets the answer directly, not the address or location of a source containing the answer.

Information Manipulation

The next more sophisticated level is that in which the information is manipulated without being changed in the operation. These systems, like those of the previous level, must store the information, not addresses. However, the system is able to manipulate the information so that statistical studies can be made on the information without processing the information (in the sense of a chemical reaction). The information goes into the manipulation operation in one form and comes out in the same form. Only operations such as counting, comparisons, and statistical distribution studies can be performed on the information.

Information Processing

The most sophisticated systems are those which store the information and have the ability to process it. The processings modify, change, combine, or alter the stored material so that the output is in an entirely different form. Processes of this type can be accomplished only on advanced computers.

Which System Is for You?

An organization contemplating the installation of a system should first clearly establish whether the in-process material will be data, or descriptive information or a combination of both. Once the nature of the material has been identified, it will be necessary to decide what level of system sophistication is desired. A system can be designed to provide (1) only locations or addresses of documents containing the required information; (2) the information as direct answers without the ability to manipulate or process, (3) the information as direct answers with added capability for simpler arithmetic manipulations such as counting and statistical distribution; and (4) the information as direct answers, with added capability for "working on" the material so that the logical or mathematical nature of the output is essentially different from the input.

Most operational systems are of the first kind, that is, document storage and retrieval systems. In operating this kind of system, the information contained in documents is described or identified at the time the document becomes a part of the collection in such a way that searches for specific information will produce identifying numbers or locations of those documents. This type of system provides searchers with lists of document numbers, lists of document locations, or lists of references in which pertinent articles have been published.

Something New—Concept Coordination

Although the storage and retrieval of information or of documents which contain information have been of considerable concern for years, until only recently there have been only two basic principles employed—classification (such as the Dewey or Universal Decimal Systems) and alphabetical filing by subject heading. These approaches, and modifications or combinations of them, have been traditionally employed in almost all applications. A third approach to the problem, concept coordination, was first put to practical use just prior to World War II in England and has been gaining rapid acceptance in recent years. Concept coordination has demonstrated that it can solve adequately the over-all document storage and retrieval problem at reasonable cost. As a result, its use is being extended rapidly in many fields.

In concept coordination systems, as a document becomes part of a collection, it is described by *terms*, or words, which identify *unit concepts* of the information in the document. These terms serve as "locators" of documents when information is needed. Documents are retrieved by correlating, or "bringing into coordination" those terms which describe the information required. A comparison is made of the document numbers listed under the terms being coordinated. When document numbers agree under, say, two terms being coordinated, those documents are sources of information on both the concepts.

How Concept Coordination Works

An example of this system is provided in Fig. 1. Document No. 988, when it became part of the collection, was described by the four terms: *distillation*, *synthesis*, *methanol*, and *butanol*. In the concept coordination approach, the search device usually consists of a number of term records, among which are those for the four terms which were used to describe document No. 988. When document 988 is entered into the search device, 988 is entered on the term records of the four terms by which its informational content was described. When information is required on the "synthesis of butanol," the searcher selects from the system the term records *synthesis* and *butanol*. He then compares the document numbers listed on these two term records and finds that No. 988 appears on both. He knows that the two concepts *synthesis* and *butanol* are part of the information in document No. 988. He then goes to document No. 988 and inspects that document to determine the nature of the information on the synthesis of butanol.

This example illustrates an *inverted* arrangement in which system unit records are *term records*. The identifying numbers of documents which contain information on the concepts are entered on the term records for those concepts. Most concept coordination systems are characterized by this inverted

(*Continued on page 481*)

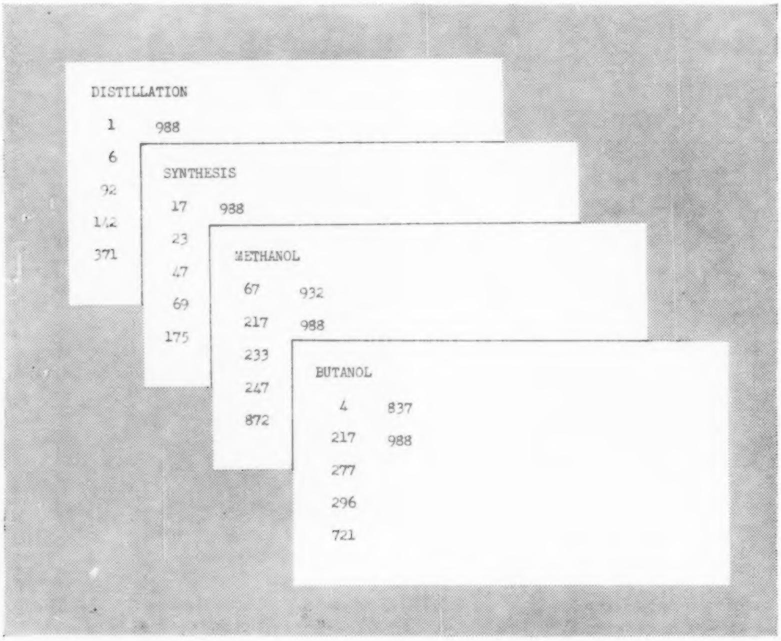


Fig. 1.—An example of concept coordination.

Current Operations
1960-1961

American Society for Testing Materials

A national technical society serving industry and government through research and standards for materials since 1898

Materials Sciences

A long-time objective of the Society — promotion of knowledge of materials — will be further advanced by the newly organized Division of Materials Sciences. Its scope — a broad concern with the nature and origin of the basic properties of materials, the relation of properties to structure, and promotion of knowledge of the fundamental nature of materials — provides a challenge and a common meeting ground for all who are engaged in the effort to provide the materials needed by our nation's industries.

The division has already sponsored two symposia: Recent Progress in Materials Sciences, and Nature and Origin of Strength of Materials.

Technical Activities

The many and diverse technical activities of the Society are focused on the two missions of ASTM—knowledge of materials, and standards. The authority of ASTM standards is largely the result of the painstaking research that gives us the technical data on which they are based.

Some Current Research Topics

Effect of atmospheric exposure on electrical contacts.
Nondestructive testing of molded reinforced plastics.
Reference radiographs for investment steel castings.
Use of electron probe to determine metal structures.
Creep and cracking of stainless steels for steamline service.
Efflorescence of masonry.
Creep testing of interior packing materials.
Extraction tests for health-hazard contaminants in flexible barrier materials.
Compression properties of sheet materials at elevated temperatures.
Cationic emulsified asphalts.
Working stresses for plastic pipe.
Tests and standards for ultra-clean rooms.

New Committees Formed

Gas Chromatography.
Sensory Evaluation of Materials and Products.
Skid Resistance.
Sampling and Analysis of Metal-Bearing Ores and Related Materials.

Standards

*T*he Society's 87 technical committees have developed over 2700 standard specifications, methods of test, recommended practices, and definitions for engineering materials. In 1960 alone, over 100 new standards were written. For over 60 years, ASTM standards have been held in high respect throughout the world because they are unbiased, authoritative, and functional. They are the product of the Society's democratic committee system. These committees, comprising consumers, producers, and general-interest authorities, are the working groups that form the backbone of the Society's standardization program. Significant new standards developed by these committees and adopted by the Society during 1960-1961 include those for:

Zinc-coated steel sheets.
Structural steel.
Zirconium and zirconium alloy forgings for nuclear applications.
Extra strength ceramic-glazed clay pipe.
Epoxy resins.
Mica bridges for electron tubes.
High-pressure cable systems.
Oxygen in molybdenum.
Tantalum rod and wire.
Specific gravity of rubber chemicals.
False set of portland cement.
Functional life of ball bearing greases.
Pressure treatment of timber products.
Elastic fabrics.
Sulfur in coal ash.
Effect of heat and air on asphaltic materials.

Publications

*T*he Society continued its efforts to supply authoritative and timely information on materials and their evaluation. Some recent Special Technical Publications include:

Building Constructions — 116 pages.
Spectroscopic Excitation — 65 pages.
Strength and Related Properties of Wood Poles — 180 pages.
Index to the Literature on X-Ray Spectroscopic Analysis — 48 pages.
Air Pollution Control — 44 pages.
Bituminous Waterproofing and Roofing Materials — 86 pages.
Durability and Weathering of Structural Sandwich Construction — 100 pages.
Effect of Water-Reducing Admixtures and Set-Retarding Admixtures on Properties of Concrete — 256 pages.
Electron Metallography — 134 pages.
Fatigue of Aircraft Structures — 146 pages.
High-Voltage Cable Insulation — 44 pages.
Materials in Nuclear Applications — 360 pages.
Newer Metals — 244 pages.
Nondestructive Testing in the Missile Industry—78 pages.
Soils — 384 pages.
Spectroscopy — 232 pages.
Treated Wood for Marine Use — 74 pages.
Road and Paving Materials — 132 pages.
Reinforced Plastics for Rockets and Aircraft — 140 pages.
Properties of Crystalline Solids — 150 pages.
Acoustical Fatigue — 72 pages.
Shear and Torsion Testing — 128 pages.
Low-Temperature Properties of High-Strength Aircraft and Missile Materials — 232 pages.
Radiation Effects and Radiation Dosimetry — 162 pages.
Adhesion and Adhesives — 72 pages.
Particle Size Determination in Subsieve Range—112 pages.
Physical Properties of Metals and Alloys from Cryogenic to Elevated Temperatures — 210 pages.

In addition, many compilations of standards for specific industries have also been published including:

Mineral Aggregates and Concrete — 408 pages.
Cement — 296 pages.
Chemical Analysis of Metals — 772 pages.
Copper and Copper Alloys — 760 pages.
Steel Piping Materials — 536 pages.
Petroleum Products, Lubricants and Related Materials (2 Vols.) — 1868 pages.
Plastics — 1240 pages.
Soaps and Other Detergents — 280 pages.
Textile Materials — 968 pages.
Industrial Water — 696 pages.

National Meetings and District Affairs

*D*uring the year, the Society organized its 18th district, to serve Oregon, Washington, Idaho, and British Columbia. Two more are authorized. In all, 35 local meetings were sponsored by the districts to give members an opportunity to hear prominent authorities on materials and materials evaluation as well as to meet national officers of the Society. A National Technical Meeting was jointly sponsored by the Philadelphia District and Committee F-1 on Materials for Electron Tubes and Semiconductor Devices.

The 63rd Annual Meeting of the Society, held in Atlantic City, N. J., June 1960, broke all records with over 3300 attending. Committee Week, held in Cincinnati, Ohio, January 30 through February 3, 1961 had an attendance of 1500.

Membership

*I*ncreasing interest in the work of ASTM was reflected in the sustained growth of membership. More individuals, companies, government departments, schools, and associations joined the Society than in any previous year, bringing the total to over 10,500. In addition, the Society now has 1757 student members as well as 6600 technical committee members who are not individual members of the Society, but who, as representatives of company members, contribute their special knowledge and experience to the work of the Society.

Finances

*T*he financial operations of the Society have resulted in a much better picture for 1960 than was anticipated at the beginning of that year. The anticipated deficit of $71,000 was cut to only $7200. For 1961, a slight surplus is anticipated on an annual budget of close to $1,500,000. These sums are apart from the vast amount of research work supported by industry, government, and individuals to provide data necessary to the Society's effort.

*T*he year 1960-61 was of considerable import for the Society. The changes which took place during the year included not only new technical activities but changes in administration which will have a long-range effect on the Society. The smoothness with which these changes were accomplished gives evidence of the dynamic strength of ASTM.

But what of the future? At present, plans are being reviewed regarding the relationship of staff services to the technical committees. Also a headquarters expansion program is being considered. In addition, the first phases of the Long Range Planning Committee's report have now been submitted. We can look ahead to continued growth in services to members, to the American industrial economy, and to the general welfare of the nation.

Reprints of this folder, a complete list of ASTM publications, and an index of all ASTM standards are available upon request.

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The Information Problem

(*Continued from page 476*)

arrangement. When system unit records are term records, retrieval is rapid and economical. A searcher goes directly to those term records which represent the concepts on which he wants information. He uses the *selective* or *parallel* searching approach. In contrast, traditional systems use *item records* as system units, and retrieval requires a *serial* or *sequential* scanning of all item records or a major portion of them to locate those bearing the desired combinations of terms.

Advantages of Concept Coordination

Concept coordination systems generally require the smallest system storage space, since the rate of growth of the vocabulary (and hence the total number of term records in the system) tends to stabilize after a representative cross-section of the collection has been described. Once the vocabulary of a system has been established, the number of system records (term records) necessary to maintain the system tends to increase very slowly regardless of the rate of document acquisition. In the traditional systems, where *unit records* are *item records*, for each new document a relatively fixed number of item records must be added to the card catalog. There is no stabilizing effect regardless of system maturity.

Why Have an Information System?

The objectives of an information storage and retrieval system in any organization should be to provide to research, management, and operating personnel all the pertinent facts they need when they need them. This type of system can be justified only if it enables all levels of personnel in an organization to make more effective judgment decisions. Obviously, the benefits of an effective information storage and retrieval system can accrue equally to the small enterprise as to the large industrial concern.

Despite the nobility of objectives of the information system, a number of constraints will be imposed by considerations such as the geographical distribution of those who will create the input to the system and the accessibility of the storage and retrieval means to those who will use it. For example, if a company has all of its research and development activities centralized at one location, the problems are appreciably different from those which arise in a multi-plant corporation where potential users may be several thousand miles from the information system. Where the user group is widely distributed geographically, provision must be made so that personnel at distant locations will be provided adequate service by the central information system. In such situations, it may well be necessary to provide for communication between the distant personnel and the central information system by teletype and to provide duplicate sets of source documents at distant locations. This is a significantly different problem from the one that exists where all personnel are at the same location as the information system.

Ask Yourself These Questions

In any situation, a first consideration will be, "is an information system really needed?" Then, "how many people will use the system?" "How high a reuse value does the information in the system have?" "What is the stability of the user group?" And "what is the frequency of use?"

A typical problem may be this: an organization has 2000 serially filed patents, all of which are pertinent to a particular type of product made by the organization. Each time it is necessary to search these 2000 patents, the searcher must serially progress from the lowest-numbered one through all 2000 to the highest-numbered one. If searches of this type are conducted frequently, a deep index of the information they contain may well be economically justified. However, if these 2000 patents are searched only once a year, the cost of installation of an information system in which all documents are deeply indexed can hardly be justified.

An entirely different type of problem is encountered when an information system is being considered as a service for a profession or a professional society. Here the problems are compounded. The system users now are not located at one or a relatively few—10, 20, or 50—plant locations. Instead, they are randomly distributed over the entire country and perhaps in foreign countries. Undoubtedly many speak languages other than English. A centrally maintained information service may be out of the question. In this situation, it would be well for the professional society to determine the best storage and retrieval approach and then to provide for the indexing of the documents at one central location. Then, terms to be used in local, independent, or autonomous concept coordination systems are provided at the end of each article published in the society's professional journal. Each location then can maintain the system most suitable for its specific needs.

A system designed to serve personnel at only one location may not have to be designed with much consideration for adaptability. On the other hand, an information system for a professional society servicing a widely distributed membership will probably have to give primary consideration to adaptability, to practically unlimited differences in local adaptations.

And Don't Forget the User

Information systems can increase the efficiency and economy of an organization's operations. Systematic and orderly access to stored information can conserve manpower and money by decreasing delay in decision making and by minimizing the duplication of previously completed work. There is no "cure-all" system approach. The justification for a storage and retrieval system must be found solely in the needs of the user group and in the quality and quantity of information contained in the collection of documents available to the user group. The differences between data and descriptive information must be recognized and the system design based on the type of material to be processed. The proper system sophistication level must be selected to fulfill the needs of the user group. Characteristics of the information and the composition and distribution of the user group are determinants of approach, physical form, and economics of service.

COMING MR&S PAPERS

Determination of the Specific Gravity of Viscous Materials—H. E. Ashton, National Research Council of Canada.

Apparatus for Controlled Slack Quenching—N. L. Carwile, M. R. Meyerson, and S. J. Rosenberg, National Bureau of Standards.

Laboratory Preparation of High-Purity Tricalcium Silicate—Milos Polivka, Alexander Klein, and C. H. Best, University of California.

In-Motion Radiography of Sergeant Missile Motor Casing—E. H. Rodgers, Watertown Arsenal.

The Effect of Temperature on Air Aging of Rubber Vulcanizates—M. J. Schoch, Jr., Hewitt-Robbins Inc., and A. E. Juve, The B. F. Goodrich Research Center.

Pressure-Differential Testing of Tubing—G. H. Symons, Wolverine Tube, Inc.

A Survey of Infrared Inspection and Measuring Techniques—D. K. Wilburn, U. S. Army Ordnance, Tank-Automotive Command.

Society Affairs

Highlights of Board Meeting

FOLLOWING ARE some of the actions taken by the ASTM Board of Directors at its meeting at Headquarters on May 9, 1961.

Planning Committee

Since it is expected that the *ad hoc* Long-Range Planning Committee will complete its work by the end of this year, the Board voted to establish a permanent Planning Committee to keep a continual watch on the objectives of the Society and how best to meet them. This committee will include the two senior past-presidents on the Board, the two vice-presidents, and one member at large.

Change in Name

The Board voted to submit to the membership at the Annual Meeting a recommendation to change the name of the Society to "American Society for Testing and Materials."

Life Memberships for Past-presidents

A change in the ASTM By-laws will be submitted to the membership to permit the Board to confer life membership on past-presidents when they have completed their service on the Board.

Symposium on Passivity

On recommendation of the Executive Committee of the Division of Materials Sciences, the Board voted to have ASTM cosponsor the Second International Symposium on Passivity, to be held in September, 1962, in Kingston, Ont. Other sponsors are the Electrochemical Society, the Faraday Society, and the Deutsche Bunsen Gesellschaft, with financial support from the National Research Council of Canada.

National T&AM Committee

The board approved ASTM membership on the U. S. National Committee on Theoretical and Applied Mechanics. This joint committee represents the United States in the International Union on Theoretical and Applied Mechanics. One of the activities of the latter body is the sponsoring of the quadrennial International Congress on Applied Mechanics.

Cooperation with JETS

ASTM will cooperate at the District level with programs of the Junior Engineering Technical Society (JETS). This group, which originated at Michigan State University in 1950, now has 800 chapters with over 24,000 members. Its purpose is to stimulate interest in engineering and science among high school students.

Nuclear Congress

ASTM will sponsor, jointly with RILEM, a symposium on Application of Atomic Physics for Tests of Materials, to be held in conjunction with the Engineers Joint Council Nuclear Congress in New York, June 4–7, 1962.

Committee Appointments

The following new appointments were made to Administrative and other committees:

Papers and Publications—R. C. Mielenz.
District Activities—E. J. Dunn, W. J. Klayer, C. S. Macnair, Cedric Willson, and F. J. Mardulier.
Templin Award—L. J. Markwardt.
Sam Tour Award—Jerome Strauss.
Richart Award—Bryant Mather and Stanton Walker.

Ordnance Advisory Committee

The ordnance advisory committee, which has been inactive for some time, was discharged with thanks.

Presidential Appointments

The following appointments by President Bates were reported to the Board for information:

F. L. LaQue to the ASA Standards Council.

G. R. Irwin to represent ASTM at the Symposium on Fracture Testing in Wurzburg, Germany, March 16–17, 1961 (see p. 489).

M. N. Clair and H. N. Perrine to the ASA Construction Standards Board.

J. R. LeCron to the ASA Sectional Committee on Standardization of Shop-Fabricated Vertical and Horizontal Metallic Storage and Processing Tanks (B86).

J. H. Foote to the ASA Sectional Committee on Use of the Decimalized Inch (B87) (J. W. Caum, alternate).

E. M. Wolf as alternate to the ASA Sectional Committee on Magnet Wire (C9).

C. E. Crompton to the ASA Sectional Committee on Chemical Engineering for the Nuclear Field (N5) (C. E. Weber, alternate).

F. E. Clarke to the Joint Committee on Uniformity of Methods of Water Examination.

The following were appointed to committees of the Engineers Joint Council:

A. A. Bates, M. N. Clair, and T. A. Marshall, Jr.—International Relations.

F. Y. Speight—Engineering Information Services and Computer Applications.

A. Q. Mowbray—Editorial Advisory.

T. A. Marshall, Jr.—Who's Who in Engineering; Secretaries.

N. L. Mochel—Government Liaison.

E. C. Shuman—Technical Planning.

J. E. Kinney—National Water Policy Panel.

M. A. Cordovi—1962 Nuclear Congress Program.

ASTM MEETINGS

Date	Group	Place
Aug. 15–18	Joint ASTM-TAPPI Committee on Petroleum Wax	Montreal, P. Q.
Aug. 19	Joint Committee on Leather and Physical Testing Committee of International Union of Leather Chemists	Washington, D. C.
Sept. 5–8	Committee D-23 on Cellulose and Cellulose Derivatives	Chicago, Ill.
Sept. 24–28	Committee D-2 on Petroleum Products and Lubricants	Detroit, Mich. (Statler)
Sept. 27–28	Committee C-21 on Ceramic Whitewares and Related Products	Bedford Springs, Pa.
	1962	
Feb. 5–9	**Committee Week**	**Dallas, Tex. (Statler-Hilton)**
June 24–29	**Annual Meeting**	**New York, N. Y. (Statler-Hilton)**
Sept. 30–Oct. 5	**Pacific Area Meeting**	**Los Angeles, Calif. (Statler-Hilton)**
	1963	
Feb. 4–8	**Committee Week**	**Montreal, P. Q. (Queen Elizabeth)**
June 23–28	**Annual Meeting**	**Atlantic City, N. J. (Chalfonte-Haddon Hall)**

Technical Committee Notes

Glass and Glass Products

Forty new and revised definitions produced by Committee C-14 have been accepted by the Administrative Committee on Standards for publication in Definitions C 162 for glass and glass products. Methods C 240 have been revised and given the new title, "Methods of Testing Cellular Glass Insulating Block."

Ceramic Whitewares and Related Products

Committee C-21 has completed preliminary work to develop a standard test for determining the extractable lead in ceramic glazes in cooperation with the Kettering Laboratory of Applied Physiology, the Baltimore City Health Department testing laboratories, and the California Department of Public Health. The data show that the hydrogen sulfide method is accurate only in concentrations below 4 ppm; for higher concentrations the dithizone (diphenylthiocarbazone) method must be used.

The final draft of a paper to be published on the results of interlaboratory development of a test for specular gloss of ceramic tile was reviewed. The test method was approved for subcommittee letter ballot. The ceramic tile subcommittee proposed that work be started to investigate the possibility of developing test methods for measuring color differences of glazed ceramic tile.

The use of uranium dioxide ceramic fuels is now well accepted in nuclear reactors, in pellet form, swaged, and laboratory-compacted elements. The nuclear applications subcommittee feels that standardizing methods and classifications of density measurements, and the establishment of quality control standards are feasible. Definitions of theoretical density and defects in fabricated ware are needed. The first work will be to determine if certain existing tests can be unified and others standardized.

The Task Group on Nuclear Grade Graphite has determined that ASTM test methods used in this industry include: B 193, C 78, C 134, C 198, C 372, C 407, C 408, and E 111. Test methods for measurement of gaseous permeability, open and closed porosity, outgassing spectrum, and grain size need to be standardized. The task group has decided that purity specifications for nuclear graphite can be established and tentative proposals can now be prepared. The various properties of fueled graphite are being explored for possible standardization.

TECHNICAL COMMITTEE OFFICERS

OFFICERS OF COMMITTEE B-3 ON CORROSION OF NON-FERROUS METALS AND ALLOYS

Left to right: W. H. Ailor, secretary, Reynolds Metals Co.; K. G. Compton, chairman, Bell Telephone Laboratories, Inc.; *missing*, E. K. Camp, vice-chairman.

OFFICERS OF COMMITTEE A-5 ON CORROSION OF IRON AND STEEL

Left to right: C. P. Larrabee, secretary, U. S. Steel Corp.; H. F. Hormann, chairman, Consolidated Edison Co. of New York, Inc.; *missing*, E. K. Camp, vice-chairman.

ASTM-ALCA JOINT COMMITTEE ON LEATHER

Left to right, seated: B. L. Lewis, vice-chairman, Tinius Olsen Testing Machine Co.; Joseph Naghski, chairman, U. S. Department of Agriculture; Milton Bailey, secretary, U. S. Department of the Navy; *standing*, Fred O'Flaherty, Tanners' Council Laboratory.

NEW ASTM PUBLICATIONS

20-Year Corrosion Report Published

Twenty-year Atmospheric Corrosion Investigation of Zinc-Coated and Uncoated Wire and Wire Products

STP 290, by Fred M. Reinhart, National Bureau of Standards, 146 pages, hard cover, price $5.50, to members $4.40.

THE VAST amount of data collected and evaluated for this 20-year report shows, among other things, that the life of a zinc-coated wire is proportional to the weight of coating, that the time rate of loss of zinc is linear, that the corrosion rate of zinc coatings is independent of the method of coating, and that strengths of copper- and lead-coated wires are not significantly affected after 20 years.

These wire tests encompassed plain and fabricated wire having galvanized coatings of from 0.2 to 3.0 oz per sq ft and also extra-heavy coatings of zinc, some with chromate treatments, and copper and lead coatings. Samples of 18 per cent chromium and 8 per cent nickel steel, and 12 to 14 per cent chromium steel (cold-drawn and air-quenched wires) were also included.

Data at the East-Coast test sites were collected by members of Subcommittees VIII and XV of Committee A-5 on Corrosion of Iron and Steel. At the Midwest and Far-West sites, faculty members designated by seven cooperating universities collected the area-of-rust data. Fred M. Reinhart, the author of this report, visited all of the sites in 1956 to estimate area-of-rust data and collect specimens for tensile strength tests and loss-of-zinc-coating measurements for the 20-year report.

In 1924, Committee A-5 inaugurated a broad program to evaluate the atmospheric-corrosion resistance of various metallic coatings and treatments of iron and steel sheets, wires, hardware, and structural shapes. This was a result of the famous laboratory sulfuric acid immersion test that proved that an acid-type test cannot be used as a reliable means of predicting atmospheric corrosion resistance. The sheet tests began in 1926, tests of hardware and various shapes in 1928, and the wire tests in 1936.

EXPOSURE SITE AT MANHATTAN, KANS.

In the fall of 1935 the size of the wire test program made it necessary to engage a warehouse in Long Island City, N. Y., and all wire specimens were directed there for collection, sampling, codification, and shipment to the eleven test sites. H. E. Smith was retained as a consultant to direct this work, with C. L. Warwick, then executive secretary of ASTM, in charge.

In 1935 it was estimated that the final cost of the wire test study would be $96,500; however, when one considers that the expected exposure time has been extended to 30 and possibly 40 years, this figure will doubtlessly be exceeded by a wide margin.

Some idea of the scope of this huge program is given by the following statistics:

From more than six miles of unfabricated plain wire collected for the program, 1430 exposure specimens 3.3 ft long were cut and mounted on 400 frames at 11 test sites. More than 30,000 individual tension tests will eventually be made on these specimens.

Farm-field fencing of the standard hinge-joint type, 39 in. high, was furnished in the same materials as the unfabricated wire. Some 560 specimens, 16½ ft long, were installed at 7 sites for a total length of nearly two miles.

Chain-link fence galvanized before and after weaving, corrosion-resistant steel, and lead- and copper-coated steel fencing was erected at 8 sites, for a total length of about ⅓ mile.

More than a mile of barbed wire with various zinc and lead and copper coatings was exposed at 7 sites.

Seven-wire strand, ⅜ in. in diameter (see cover), comprising 13 specimens covered by 0.8 to 2.6 oz per sq ft of zinc and one lead-coated specimen was exposed at each of 10 sites, for a total length of nearly ¾ mile.

For anyone concerned with protecting wire or wire products from the ravages of atmospheric exposure, this 20-year report offers a wealth of valuable data and information, amassed at great labor and expense and analyzed by experts in the field.

Physical Properties of Metals and Alloys from Cryogenic to Elevated Temperatures

STP 296, 214 pages, 8½ by 11, paper cover, price $4.75; to ASTM and ASME members $3.80.

THIS PUBLICATION, prepared by Battelle Memorial Inst., under the auspices of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals, is a compilation of physical-property data for six metals and their alloy systems. The metals covered are aluminum, cobalt, iron, magnesium, molybdenum, and nickel, and their alloys. Data are presented in the form of data sheets and curves covering thermal conductivity, linear thermal expansion, specific heat, electrical resistivity, and magnetic permeability. Emphasis has been given

to data over a range from cryogenic (−457 F) to elevated temperatures (4500 F).

The data contained in this report were compiled principally from information supplied by companies, organizations, trade bulletins, published technical literature, and U. S. Government publications. All data were reduced to English units and transposed to uniform data sheets, numbering about 650. An effort was made, in reducing and plotting the data, to maintain the interpretation intended by the authors.

A table of conversion factors is included for convenience in converting units to metric equivalents.

Methods of Metallographic Specimen Preparation

STP 285, 140 pages, hard cover, price $4.50, to members $3.60.

THE PHRASE "METALLOGRAPHIC specimen preparation" refers to the surfacing, prior to etching, of metal specimens to be studied with the microscope. With the exception of the completely different processes involved in chemical and electrolytic polishing, the basic mechanism of specimen preparation has undergone no change since nearly a century ago. It consists of removing successive layers of the specimen through the mechanical action of increasingly finer abrasives. However the choice of techniques and materials to achieve these objectives is a most complex matter. In the face of so many variables good results depend largely on experience and judgment, and metallographic specimen preparation came to be considered an art.

Progress in the art is covered in part by the topics of this symposium volume. Three general problem areas have motivated improvements in procedures:

1. The correlation of microstructure with the mechanical and physical properties of metals in the range where microstructural details are of the order of the resolving power of the instruments employed. Surfaces to be used for such studies require the utmost in careful handling.

2. The production control of a single structural characteristic and hence the need for preparing and examining quantities of specimens in a short time.

3. The remote metallography of irradiated specimens.

This symposium volume is thus concerned with the present-day procedures in employing a century-old basic idea and with descriptions of recent methods of specimen preparation.

The contents:

MATERIALS SCIENCES

NBS Education and Training Program

HOW BEST TO maintain the habit of rigorous study after a formal academic degree has been attained is a problem that must be faced by everyone in research. Some say this can be done simply by individual and voluntary effort. Others feel that the habit needs to be nurtured by a continuing program of graduate education. Among the groups that hold to the latter view is the National Bureau of Standards, which sponsors a broad employee development program oriented to the education and training needs of all staff members. The program, implemented through the NBS Graduate School, offers 40 courses a year, both graduate and undergraduate, in the physical sciences and engineering. Non-Government facilities are also used. Since establishment of the graduate school in 1908, more than 15,500 registrations have been recorded, and over 270 graduate degrees have been awarded by 40 different universities partly on a basis of credits and thesis work in the graduate school. During 1960 there were 1322 registrations and 72 courses offered at the Washington, D. C., and Boulder, Colo., laboratories.

NBS Postdoctoral Research Associateships

The Washington and Boulder laboratories are currently hosts to 13 young scientists who are taking advanced studies in a program sponsored jointly by NBS and the National Academy of Sciences–National Research Council. Since the program was established seven years ago, 44 young men including the present 13 have been awarded research associateships.

The plan provides advanced training for creative young scientists who have shown promise of leadership in fundamental research. Not only does the program provide for training of the best young scientists, it also provides for a "cross-fertilization" of ideas, bringing results of the research and training both to the Bureau and to the organization with which the scientist ultimately associates on a permanent basis.

ASTM Graduate Fellowship Program

ASTM's program for support of graduate study, as outlined in the March issue of *MR&S*, page 214, provides probably one of the most liberal stipends for a year of graduate study available anywhere—$6500. The program, which was established in 1959, provides a total of five $6500 fellowships—one each year—and 25 $1000 grants-in-aid which will be allocated over about five years. The first $6500 fellowship went to R. E. Olsen of the University of Illinois in 1959, and the second went to Richard Krock, Massachusetts Institute of Technology.

This ASTM educational program is designed to encourage research and study contributing to the science and knowledge of materials.

Materials Research Center Established at Rensselaer

RECENT PROBLEMS in several areas of science and engineering have created an awareness of the need for more fundamental research in the field of materials. In partial answer to this need, the National Aeronautics and Space Administration has approved a proposal to establish an Interdisciplinary Materials Research Center at Rensselaer Polytechnic Inst. The major areas of investigation will be solid-state physics, nonmetallic solids, and physicochemical properties of materials. The major equipment for the program will include an electron microscope, complete X-ray diffraction and

fluorescent equipment, infrared spectroscopic equipment, and a nuclear magnetic resonance laboratory.

One of the main objectives of the Interdisciplinary Materials Research Center is to promote the training of promising graduate students in an atmosphere in which engineering and the sciences are amalgamated. It is contemplated that by 1965 approximately 25 men will have received Ph.D. degrees with support from this program.

Strength of Crystals

A MATERIALS CONFERENCE international in scope, devoted to "The Impact of Transmission Electron Microscopy on Theories of the Strength of Crystals," will meet in Berkeley, Calif., July 5–8, 1961.

Organized along the lines of the well-known Gordon Research Conferences, the meeting is presented by the Inorganic Materials Research Division of the Lawrence Radiation Laboratory, U. S. Atomic Energy Commission, in cooperation with the University of California Department of Mineral Technology.

Among the scientists who will contribute to the program are M. J. Whelan, P. R. Swann, A. S. Keh, S. Weissmann, P. B. Price, J. Washburn, S. Amelinckx, R. L. Segall, R. B. Nicholson, G. Thomas, J. Nutting, J. Marcinkowski, D. Wilsdorf, and J. C. M. Li.

New Superconductive Alloys

J. E. KUNZLER of Bell Telephone Laboratories reported to the Spring Meeting of the American Physical Society in Washington, D. C., April 27, that a ductile alloy of columbium (niobium) and zirconium will remain superconducting at liquid-helium temperatures in a field of 80,000 gauss while carrying 10,000 amp per sq in. At the same meeting, B. T. Matthias reported the discovery of a series of new ductile alloys, made of molybdenum and technetium, which become superconducting at temperatures near 16 K.

Critical Data on Chemicals, Hydrocarbons

The critical tables projects to develop data on physical, thermodynamic, and spectral properties of chemicals and hydrocarbons sponsored by the Manufacturing Chemists' Assn. and the American Petroleum Inst. are going forward in a new location—Texas A & M. Both projects were transferred in April from Carnegie Institute of Technology, where for some years they were under the direction of F. D. Rossini. The MCA project was started in 1955. When the program at Texas A & M gets into full swing, it will employ some 17 persons under the direction of Bruno J. Zwolinski.

Both projects will develop critical data in six major areas: physical and thermodynamic, infrared spectral, ultraviolet spectral, Raman spectral, mass spectral, and nuclear magnetic resonance spectral data. The research involves examination of world-wide literature references, and both experimental and theoretical investigations.

Calculation of properties based on proved structure-property relationships will be carried out on a new high-speed IBM-709 electronic computer recently installed at Texas A & M.

ASTM Committee E-13 on Absorption Spectroscopy will continue to cooperate with the projects in matters relating to collection and publication of absorption spectral data.

DISTRICT ACTIVITIES

CHICAGO

The Chicago District, with members of Committee D-10 on Packaging, met in Chicago on April 11. C. S. McNair, chairman of the council, told of the experience of the first few speakers of the new Chicago District Council technical lecture service. This service makes available some 75 speakers, covering topics largely in ASTM fields of interest, to all educational institutions in the council area.

Those present heard ASTM President A. Allan Bates describe his recent trip to Russia. Dr. Bates observed that the Russians admire the United States as the outstanding example of an industrialized society and seek to know as much about us as possible. Although we, in turn, know very little about the Russians, the Iron Curtain that has done much to discourage our interest in the present Russian culture has been relaxed to a certain degree for tourists and to an even greater degree for scientific personnel. It was on one of these technical inspection tours that President Bates toured Russia and took many photographs.

Dr. Bates reminded his audience that the waves of the Rennaissance had swept Europe only to the Russian borders, and the Industrial Revolution did not reach Russia until the 19th century. The Bolshevik revolution signalled the plunge of Russia into the industrialist society of today—full of vibrant energy, great promise, and with all of the vitality of the westward expansion of the United States. It is this spirit that completely occupies the Russian citizen today. His thoughts about his paternalistic government are ones of satisfaction—this is the most "democratic" government he has ever experienced.

One of the most pressing problems in Russia is housing. World War II left 25 million homeless; the industrialization of Russia has brought 75 million farmers into the cities. The solution was mass production of apartment dwellings on a highly standardized basis. The latest approach to apartment dwellings has been a completely prefabricated concrete unit. The unit, as big as a large house trailer, contains a bedroom, living room, shower, kitchen, and hall. The units interlock structurally and can be trucked to the erection site. A large rail crane stacks them in the desired numbers, and appropriate staircase sections are added. Thus extensive apartment dwellings can be erected and ready for occupancy in a matter of days.

Dr. Bates inferred that, for peasants moving to the great steel cities of Magnitogorsk and Sverdlovsk or to the industrial cities of Stalingrad, Kharkov, and Moscow, with their cultural and sports programs and their great outlying suburbs of apartments rising like the flowers of spring, the experience must be like that of the Goths on first seeing Rome.

NEW YORK

A FOUR-WAY joint meeting was held at the Engineering Societies Building in New York City, Wednesday evening, April 19. The four groups were: Metropolitan Section, American Society of Civil Engineers; Concrete Industries Board of New York, Inc.; Portland Cement Assn.; and New York District of ASTM.

ASTM President A. Allan Bates, vice-president of PCA, was the principal speaker. The meeting was arranged for the two sponsoring societies by J. S. Pettibone for ASTM and M. D. Morris for ASCE. Mr. Morris, acting as meeting chairman, introduced R. H. Dodds, president of the Metropolitan Section of ASCE; Admiral J. J. Manning, managing director of CIB; W. J. MacIntosh, director of the New York office of PCA; Lincoln T. Work, chairman of the New York District Council of ASTM; J. S. Pettibone, secretary of the New York District Council; and ASTM Executive Secretary T. A. Marshall, Jr.

Prof. J. M. Garrelts of Columbia University received an award from the Reinforced Concrete Research Council "in recognition of his service to the

council as secretary from 1948 to 1960."

Apropos of Dr. Bates' talk on construction methods in the Soviet Union, the chairman observed that an interesting contrast between construction methods in the United States and in the USSR is that, in our country (as Admiral Manning pointed out), concrete is actually manufactured on the job, whereas in the Soviet Union building crews are just small assembly forces, because precast, prestressed concrete units are mass-produced in a factory and delivered to the job site ready to install.

SOUTHWEST

A CROSS-SECTION of leaders in the construction industry of north central Texas met in Dallas the evening of April 10 for dinner and a talk by ASTM President A. Allan Bates. In addition to the ASTM Southwest District, the meeting was sponsored by the Dallas Chapter of the Texas Society of Professional Engineers, the Dallas Chapter of the Construction Specifications Inst., and both the Dallas and Forth Worth branches of the Texas Section of the American Society of Civil Engineers.

During Dr. Bates' talk, in which he compared construction standards and methods in the United States with those in the USSR, the very attentive audience asked so many questions that Dr. Bates almost had to fight to get equal time for his prepared material. Most of those in the near-capacity audience of 170 were surprised at the lateness of the hour when the meeting adjourned.

Promotion for the meeting was handled by the Attendance Committee of the Dallas Chapter of TSPE, under the direction of Chairman Charles E. Balleisen. Seated at the head table with Dr. Bates were George H. Meffert, president of the Dallas Chapter of TSPE; Grady Creel, president of the Fort Worth ASCE branch; Elmer Nooner, vice-president of the Dallas ASCE branch; Henry J. T. Martin, director, Dallas Chapter, CSI; and Cedric Willson, vice-chairman of the ASTM Southwest District Council.

WASHINGTON, D. C.

THE ASTM Washington District was host at a luncheon meeting for students and district members at the Social Center, Catholic University, Washington, D. C., on Friday, April 28. About 125 students and district members attended. Donald E. Marlowe, dean of engineering, introduced Monsignor McClafferty, assistant to the rector, who welcomed the gathering to the Catholic University campus.

Fred F. Van Atta, Treasurer of ASTM, spoke on "How the ASTM Serves the Engineering Profession." He described the ASTM as a democratic organization. Actually, he said, the engineering profession, science, and industry serve themselves by working through the ASTM technical committee organization in stimulating research and in developing standard specifications and methods of tests for materials.

W. A. Wildhack, special assistant to the director of the National Bureau of Standards, described the activities of the Bureau, which include not only the custody of standards of measurement (as he put it—the pint, the peck, and the pound) but also the development of methods for measurement of physical constants, properties of materials, and the development of methods of testing. He emphasized the cooperation the Bureau maintains with other standardizing groups, including the technical and professional societies, and described briefly some of the other advisory services to government agencies that the Bureau provides. The meeting was concluded by a tour of the Bureau.

Harold Allen of the Bureau of Public Roads, and chairman of the Washingtion District Council, served as chairman of the meeting. John M. Griffith of the Asphalt Inst. was chairman of the Program Committee. He was ably assisted by R. E. Bollen of the Highway Research Board and by Professors F. A. Biberstein (Catholic University) and H. A. Lepper (University of Maryland).

WESTERN NEW YORK–ONTARIO

"INDUSTRIALIZATION and urbanization led to the Renaissance in western Europe—it may lead to a similar Renaissance in the Soviet Union." So said ASTM President A. Allan Bates, speaking before a Western New York–Ontario District dinner meeting in Niagara Falls, Ontario, April 20.

The moving in the last generation and a half of many millions of Soviet citizens from rural to urban areas is similar to the movement during the early Middle Ages in Western Europe which provided the impetus for the Renaissance, a period in Western Culture which was not planned but was brought upon the people of Italy, France, and England by the forces of history. Dr. Bates portrayed a vast mechanized residential construction program under way in the Soviet Union, and along with this housing program the building of vast recreational facilities. The limited living quarters have forced the Soviet Government to provide its people with cultural and recreational facilities on a large communal scale. Unwittingly, this may lead to a sociological, intellectual, and economic change parallel to, but not necessarily the same as, the Renaissance.

Prior to Dr. Bates talk, student prize awards were presented to students from various colleges in the area. Those receiving awards were from the State University of New York, Alfred University; Niagara University; Canisus College; University of Rochester; University of Buffalo; and Rochester Institute of Technology.

Arrangements for the meeting were made by Robert Terrill, chairman of the District Council and vice-president of Spencer Kellogg & Sons, and by Melville Ehrlich, secretary of the Council, who is associated with the American Lubricants Co.

PITTSBURGH

At a meeting held by the Pittsburgh District Council, Wednesday, April 26 at the University Club in Pittsburgh, ASTM President Bates presented certificates to students selected to receive the 1961 awards granted by the Council. Most of the students receiving the awards had outstanding scholastic records and many were working on advanced engineering problems under grants from various industrial and governmental agencies. Each student was presented in turn to the president by a member of the District Council. Students receiving awards were: G. B. Batson and J. H. Poellot, Carnegie Institute of Technology; Tu-Lung Weng and P. W. Hill, The Pennsylvania State University; W. L. Hosick and Robert Sanders, University of Pittsburgh; and W. L. Fourney and M. J. Hudak, Jr., West Virginia University.

Following the presentation of Awards, Dr. Bates gave a talk on "Observations on Construction Methods Being Used in the Soviet Union," in which he speculated on the effects that rapid urbanization may have on Soviet culture.

Arrangements for the meeting were made under the direction of E. J. Holcomb, Aluminum Company of America, chairman of the Pittsburgh District Council; and W. E. Walters, Pittsburgh Testing Laboratory, secretary of the Council.

DETROIT

President A. Allan Bates addressed the Detroit District meeting held in cooperation with the Michigan Section of the American Society of Civil Engineers and the Michigan Chapter of the American Concrete Inst., April 25, at the Horace Rackham Memorial Building in Detroit. Speaking on "American and Soviet Construction Materials and Methods for the Future," Dr. Bates mentioned that the Soviet Union is now using concrete as its major building material and that it is

likely that this will continue for some time in the future. The availability of the basic ingredients of concrete made this an ideal building material for the rapid urbanization of the Soviet people. Of course, he emphasized, it does not necessarily follow that the construction industry in the United States will use concrete to the same extent. However, the techniques that the Soviet construction industry is using may, in part, be adaptable to the needs of the American economy.

Before his talk, Dr. Bates presented student prize awards to students from the University of Michigan, Michigan State University, the University of Detroit, and Wayne State University.

Arrangements for the meeting were made under the direction of C. S. Nixon, General Motors Corp., chairman of the Detroit District Council.

Board Approves Recommendation To Form Two New Districts

At a meeting held at National Headquarters on April 11 the Administrative Committee on District Activities voted to recommend to the Board of Directors the formation of two new Districts. The move was approved by the Board of Directors on May 9. A Central Plains District will serve Kansas, Nebraska, Iowa, and part of Missouri. A Northern Plains District will serve North and South Dakota, Minnesota, and part of Wisconsin. The recommendations were based on an extensive survey of ASTM members living in the areas concerned as well as consultations with district councils in surrounding areas. In addition, the state of Montana will be included in the recently formed Northwest District. If the new districts are formed, all of continental United States, except Alaska, will be served by the district structure.

Work on the revised Charter for Districts and Manual for District Operation has progressed to the point where it is hoped that drafts can be presented at the 64th Annual Meeting. A special session for district officers and councilors and others interested in the district program will be held during the meeting, on Thursday evening, June 29, at 8:00 p.m. It is hoped that, following discussions with the officers and councilors of the various districts, the revisions can be presented to the Board of Directors at their meeting in September, for formal approval. ACDA has been working on the revisions to the charter and manual for more than a year, and extensive debates and consultation with various district officers and staff members went into the preparation of the new material.

Plans for the future include the feasibility of having districts outside the continental United States, the development of more districts in the United States by subdivision of present districts, and the encouragement of more autonomy for districts.

ACR NOTES ADMINISTRATIVE COMMITTEE ON RESEARCH

Dry Friction

By E. I. SHOBERT II[1]

There has been considerable interest in recent years in the field of very pure materials and their reactions and interactions. In contrast, this article emphasizes the fact that there are areas in which gross impurities are important, and when they are not present they must be supplied.

Dry friction, a very common and ordinary thing, is useful in such simple circumstances as writing with a lead pencil, automobile tires on the road, and friction clutches. The simplest physical laws have been used to describe the phenomenon, but it is only when measurements are attempted that the inherent complications become apparent. By dry friction, of course, we mean the rubbing of two surfaces under circumstances in which no lubricant is added purposely.

Those concerned with the operation of brakes, carbon brushes, and dry bearings have realized for some time that the materials involved play only a small part in the determination of friction. In fact, the wear or dusting of carbon brushes and bearings under high-altitude conditions led to work which has shown that surrounding atmospheres and circumstances are as important in dry friction as the materials themselves, showing that the atmosphere actually has provided a lubricant. In the effort to make the operation of such things as bearings, brushes, and brakes suitable for the full range of ambient conditions available on the earth and outside the atmosphere, much has been learned about the mechanism of dry friction. It has been found, in general, that successful operation of most of these devices under ordinary circumstances is dependent upon such things as atmospheric humidity, organic and inorganic contaminants, as well as the properties of the materials themselves.

In contrast to fluid friction, dry friction involves extremely high rates of shear (for instance, 15×10^{10} sec^{-1}), such as are noted when the relative velocity of two surfaces is divided by a dimension on the order of that of a single molecule. To occur without damage or wear, this shear must take place between atoms or molecules in which the electrons are tightly bound and whose attractive influence cannot extend beyond extremely short ranges. In the case of metals, cold welding can occur through the exchange of free electrons, which, in the solid metal, produce the greater part of the cohesion. These bonds are immediately formed at a clean contact. Since fracture takes place at a weak point, it does not necessarily take place in the welded surface but at some other place behind it, with resulting roughening. To this point, we speak of adhesion wear, but the roughening of the surfaces soon leads to interlocking and abrasive wear.

When seizure appears between nonconductors, it is caused by covalent bonds of valences that have been left free beneath rubbed-off atoms. These bonds are rapidly formed, although more slowly than the metallic weld.

Lubrication means providing sliding surfaces with a more or less complete layer of laminar molecules, which endure the sliding without permitting strong free valences and which separate the contact surfaces so as to prevent high exchange of conducting electrons. For good performance, the lubricating molecules must adhere to the contact members.

Under circumstances in which moisture is frozen out at low temperatures or eliminated by vacuum or high altitude, materials such as graphite, which in normal atmosphere slide without undue wear, become very high in friction with the result that there is seizure and drastic destruction. This is prevented in many cases by the addition of materials such as barium fluoride, lead iodide, lead sulfide, and molybdenum disulfide, which maintain a surface film, not necessarily continuous, within which shear can take place without seizure in the contact members. The presence or absence of oxygen is also important, since the oxide films on copper, steel, and other materials have lubricating effects, that is, they prevent cold weld or

[1] Manager of Research, Stackpole Carbon Co., St. Marys, Pa.

seizure that may lead to rough surfaces with interlocking and galling.

Organic contaminants, while effective when present, are unreliable in some cases where apparatus must operate over an extremely wide range of temperatures, because they are often decomposed.

Electrical brushes and bearings have been built which operate under a wide range of atmospheric and vacuum conditions, and it is interesting to note that the essential principle is that of providing a source of contamination which prevents cold welding.

The ASTM Bibliography and Abstracts on Electrical Contacts, published as *STP 56-G* through *STP 56-N* inclusive, includes all of the pertinent references on this subject for anyone who wants to look into it in more detail.

DVM Fracture Conference at Würzburg[1]

DVM-TAG, THE FIRST large post-World War II meeting of the Deutscher Verband für Materialprüfung (German Society for Testing Materials), was held in Würzburg, Germany, on March 16 and 17, 1961. Nearly 600 members and guests of DVM attended, largely from West Germany, but also from 14 European countries. The theme of the meeting was "Fracture Phenomena and Fracture Testing for Structural Materials."

In his opening remarks, the president of DVM, Hans Diergarten (SKF—Schweinfurt), noted that years of study have not eliminated fracture problems and that their importance to modern technological goals is such that international coordination of research and testing is most valuable. Through its meetings and its three-language publication, *Materials Testing*, DVM assists this coordination.

The papers reflected, for the most part, the sound objective approach characteristic of German scientific work. Appearance features of fractures were given most attention. These ranged from excellent electron microscope studies of cleavage facets to large flakes in steel rails. Investigations of crack propagation with the assistance of superimposed acoustic vibration, discussed by F. Kerkhof, were also noteworthy.

It is understood that many of the papers presented at the meetings will be published in *Materials Testing*. The titles were as follows:

The Present Position and Recent Results of Fracture Theory—H. Rumpf
Recent Ideas on Initiation and Propagation of Fracture—A. Kochendörfer
Fracture Propagation in Brittle Materials—H. Schardin
Fractrography—O. Werner
Microfractography in Connection with Notch Impact Testing of Steels—W. Dienst
Research on Fracture Processes Using Ultrasonics—F. Kerkhof

DVM PRESIDENT HANS DIERGARTEN

Fracture Behavior of Concrete Under Multiaxial Stress—H. Weigler
Fracture of Tubes Under Nonhomogeneous Multiaxial Stress—D. Uebing
Progress in Development of Crack Toughness Fracture Tests—G. R. Irwin and J. E. Srawley
Structural Changes and Processes in Fatigue Fracture—M. Hempel
Fracture Development During Fatigue Stressing of Variable Amplitude—E. Gassner
Fracture and Twinning in Steel—C. A. Verbaak
Unfamiliar Phenomena in Fatigue Fracture of a Bronze Alloy—H. Sigwart
Fractures in Rails—E. Martin
Fracture Appearance of Tool Steel Bend Specimens—A. Krisch
Correlation Calculations in Materials Testing—W. Gerisch

The "progress" referred to in the title of the Irwin-Srawley paper is largely the work of the ASTM Special Committee on Fracture Testing of High Strength Metallic Materials.

On the evening of March 15 the conferees were given a lecture and a tour of the Main-fränkischen Museum at the Marienburg Fortress by the museum director, Max von Freeden. On the following evening the entertainment was a string quartet concert by four professors from Bayrischen Staatskonservatoriums. Both were well attended.

[1] This report was prepared by G. R. Irwin and J. E. Srawley, U. S. Naval Research Laboratory, Washington, D. C. Dr. Irwin served as official representative of ASTM at the conference.

Plans Under Way for Sixth World Power Conference

THE U. S. NATIONAL COMMITTEE of the World Power Conference has begun plans for taking part in the Sixth Plenary Meeting of the World Power Conference, to be held in Melbourne, Australia, October 20–26, 1962. At its annual meeting in Washington, D. C., on January 23, the committee appointed a group to select authors and subjects for the papers to be submitted by the United States at the Melbourne meeting.

Twenty papers have been allotted to the United States. A list of titles, authors, and abstracts is to be furnished to the Australian National Committee, host for the 1962 meeting, by June 30, 1961.

The theme of the meeting will be "The Changing Pattern of Power." Papers are expected to emphasize the changes that have taken place in power production, transportation, and utilization since the Fifth Plenary Meeting in 1956, and to include forecasts of expected future developments.

The Secretariat for the U. S. National Committee is furnished through the Engineers Joint Council, 29 West 39th Street, New York 18, N. Y. All communications should be sent to the Secretary, U. S. National Committee, World Power Conference, at that address.

Whiteware Research Association: A New Research Group Formed

A NEW research association has been formed in the whiteware industry. Temporary officers have been appointed and a professional research organization will be chosen in June to identify the major problems in the ceramic whiteware industry, to evaluate needed research programs, and determine how best to implement these programs. The seeds for this new association were sown three years ago when interested parties reviewed the situation of the whiteware industry. They recognized that all industry-wide research programs had suffered an almost complete demise at the beginning of World War II. Following the war the level of foreign imports had risen to an astonishing degree, and the increase in volume of inexpensive nonceramic substitutes reduced the amount of research funds available for industry-broad research work.

The financing of WRA has been initiated by requesting $1000 per year from whiteware producers in the United States. WRA president, Joseph F. Estes, Haeger Potteries Co., Dundee, Ill., has indicated that $34,000 have been appropriated so far.

RANDOM SAMPLES

Aluminum from Clay

OLIN MATHIESON Chemical Corp. has announced an important breakthrough in industry's long search for a commercially practical way to make aluminum from common clay. The corporation says it has developed, through the pilot-plant stage, an economical process for purifying aluminum sulfate.

The aluminum sulfate produced by Olin's acid process can be processed into alumina, the basic raw material for the manufacture of aluminum. The present source of alumina is bauxite, and the supply of this material within the United States is limited.

Most alumina plants have been located on deep-water ports to reduce the cost of bringing in ore from the tropical "bauxite belt." The Olin acid process opens the possibility of placing a complete aluminum plant on one site where coal for electric power is cheap, since the shales associated with most coal could be an excellent source of alumina.

Many processes have been proposed for extracting aluminum sulfate from alumina-bearing clays and shales. What makes Olin's new method attractive economically is the large size and purity of the crystals it recovers in the crystallization step of these processes—crystals $\frac{1}{8}$ in. to $\frac{1}{16}$ in. in diameter, against less than $\frac{1}{100}$ in. for earlier processes.

Aluminum sulfate normally forms microscopic, soft, mushy crystals that are difficult and costly to separate from the impure solution. Crystals produced by the Olin process are coarse and sandlike—simple and inexpensive to handle. The difference in handling the two is analogous to trying to wash dirt from mud, as compared with simply washing dirt from sand.

Plans are now under way to pilot the next step in this complex chemical problem. Preliminary laboratory work on this next step has been very encouraging. Production costs of the process have been estimated, and they are competitive.

The United States aluminum industry presently obtains more than 80 per cent of its bauxite from overseas sources, including Jamaica, Surinam, the Dominican Republic, Haiti, and British Guiana. Some domestic bauxite is mined in Arkansas and other southern states, but it contains less alumina.

Most aluminum is derived from bauxite containing from 45 to 60 per cent alumina. Olin's acid extraction processes can start with material with an alumina content of as little as 20 per cent.

New Light Bulb Made Shatterproof with Silicones

A COMMON safety hazard—exploding light bulbs—has been overcome in a new incandescent lamp through the use of silicone adhesives and glass yarns. Developed and marketed by Duro-Test Corp., North Bergen, N. J., the new lamp—named "Flamescent"—is truly shatterproof. It can be dropped onto a hard surface without exploding into a shower of glass. While in use (and hot) it can be dipped in ice water without danger of flying glass fragments (see cut).

The bulb consists of a glass shape wound with Fiberglas yarn. The glass and yarn are bonded into a single unit with a rubbery Dow Corning silicone adhesive. Several materials were tested, but only the silicone adhesive remained transparent and resilient despite long, continuous exposure to the heat of the lamp.

World's Ablest Computer Goes to Nuclear Research Center

STRETCH, billed by its makers, IBM, as "the most powerful computer in the world," has just been delivered to Los Alamos Scientific Laboratory in New Mexico. It was shipped from IBM in Poughkeepsie to the pine-forested plateau in Los Alamos on six trucks, the 2000-mile journey taking about a week. In that length of time, the new computer is capable of completing more than 250 billion computations.

In a week's time, STRETCH can simulate—within itself—a complete hydrogen weapon test. It could analyze the propagation of shock waves and their effects, determine the intensity of radiation, and examine the resulting fallout, taking into account varying meteorological conditions during the hypothetical detonation.

In addition to its use in weapons studies, STRETCH will play an important role in the development of a nuclear-powered rocket engine for space exploration, in the attempt to produce controlled power from thermonuclear

Courtesy Dow Corning Corp.

SHATTERPROOF BULB WITHSTANDS ICE WATER TEST

One drop of ice water caused the ordinary bulb (left) to explode. But a steady stream has no effect on the Flamescent bulb.

fusion, in the design of nuclear reactors, and in the study of the biomedical effects of radioactive fallout.

In "stretching" existing computer technology, IBM engineers developed a system which makes use of ultrafast circuits, transistors, and circuit components. Perhaps most important, however, are new concepts in simultaneous operation. STRETCH operates on an assembly-line basis—each part completing a task and passing on the work to another machine element. Work on another task then can begin while succeeding elements complete their work on the previous job.

Six magnetic core memory units overlap in operation to increase the flow of data. The equivalent of more than 1,500,000 decimal digits of data can be stored in these units, with data retrieved from any unit in little more than 0.000002 sec. A small, extremely high-speed index register memory makes data available in 0.0000006 sec.

Since STRETCH is organized to operate several of its storage units at the same time, a continuous flow of more than a million words a second can take place, with a peak flow rate capability of about three million words a second.

With the system using up data at this enormous rate, a magnetic disk file has been developed to feed information into the computer. In 1 sec, 1,200,000 digits of information can be transferred from the file to the core storage units. The file's entire vocabulary of 2,097,152 words may be read to or from core storage in less than ½ min.

A "look-ahead" device anticipates instruction and data requirements of the system, greatly boosting the effective memory speed. This unit acts as a reservoir, lining up instructions and information to be processed a fraction of a second before they are needed to provide a flow of information to arithmetic and logic units.

Decreasing Greasing

AUTOMOTIVE designers are now working on plans for cars that will need almost no maintenance during their first year of operation. Cars today require less lubrication than even last year's models—two manufacturers claim that their 1961 lines will require no chassis lubrication before 30,000 miles, or perhaps three years. But the problem of changing oil remains, and much expensive research would have to be done before a truly "greaseless" car could be achieved. Moreover, since almost half of all cars on the road are less than five years old, the average owner will probably change models before he has a chance to realize the long-term merits of completely greaseless operation.

A car that could be kept almost maintenance-free for a year is both practical and feasible, however, and several factors contribute to the interest in producing such a car. Motorists would naturally welcome the idea of fewer lubrications, and auto manufacturers, who have long appreciated the sales potential involved, have already introduced many innovations that reduce the amount of lubrication necessary and prolong the period between lubrications. Since 1950, there has been a gradual decline in the number of grease fittings on American cars, and the lubricant manufacturers have, over the past few years, introduced many new greases and oils that are much more efficient than earlier types.

The most recent step toward maintenance-free cars is the high performance seal—without proper sealing, lubricants gradually leak out or become contaminated by water, grit, or other corrosive substances. Plastic parts may also figure largely in reducing car maintenance problems; nylon or Teflon sleeve bearings, washers, and bushings have stood up well under extensive performance tests for several years. They usually do not replace metal at points of heavy wear, but they are finding increased use in a number of automotive applications. Teflon's low stick-slip antifriction properties, as well as its chemical and thermal stability, make it particularly useful. But although Teflon and other plastic parts function well without grease, their performance is still usually improved by lubrication, particularly if they have already been impregnated with a solid film-type lubricant.

Another important step forward is the introduction of molybdenum disulfide; since its adoption about five years ago as a standard constituent in the grease of permanent lubrication systems, its use has grown about 25 per cent. Molybdenum disulfide-based greases have unusually good properties of adherence and lubricity; consequently they are used where weathering and other conditions tend to remove lubricants, and where high-performance lubrication is needed.

The proper interval between oil changes is still open for discussion. Although motor oils have been improved and the length of time between oil changes extended, the longest interval now recommended by any automobile manufacturer is only 6000 miles. The American Petroleum Inst. recommends oil changes every 30 days in winter, and every 60 days in summer, with mileage between changes never to exceed 2000. Thus, while there is an immediate prospect of fewer chassis lubrications, the service stations still have their work cut out for them.

Industrial Bulletin
Arthur D. Little, Inc.
February, 1961

MATERIAL QUESTIONS

NEARLY EVERY day the mail at ASTM Headquarters includes some questions about materials, specifications, test methods, or related problems. We feel that the answers, many of which are based on information given us by officers of committees in their capacity as committee officers, are of general interest. For the most part inquiries we receive relate to the activities of the Society, either standards, research work, or publications. Often, an inquiry is such that the services of a consultant or independent testing or research laboratory is obviously required; in this event we do not hesitate to so recommend.

Commutator Wear

Is there a standard method of testing the abrasive effect or the wearing effect of the parts in a mica, copper, carbon-brush commutator? We are particularly interested in knowing whether there is any standard apparatus or method of testing wear of the copper and mica in commutators that are of the "flush" type.

• We know of no such standard procedure either in ASTM or elsewhere. Considerable experience in one laboratory, measuring both brush and commutator wear on all types of machines, including the combination you mention, indicates that the wear is a very complicated function of the type of commutator, the machine itself, its operating conditions, and the brush material. (EDITOR'S NOTE.—See "Dry Friction," p. 488)

Printed Wiring

What ASTM publications are there dealing with or related to printed wiring?

• The several that deal wholely or partly with this subject are:

Symposium on Solder, STP 189, 1956.

Symposium on Materials and Electron Device Processing, STP 300, in press.

T. D. Schlabach, E. E. Wright, A. P. Broyer, and D. K. Rider, "Testing of Foil-Clad Laminates for Printed Circuitry," ASTM BULLETIN, No. 222, May, 1957, p. 25.

Tentative Recommended Practice for Etching and Cleaning Copper-Clad Thermosetting Laminates for Electrical Testing (D 1825–61 T).

Proposed Tentative Specification for Copper-Clad Thermosetting Laminates for Printed Wiring (Annual Report Preprint of Committee D-9 on Electrical Insulating Materials, 1961).

In addition, there are other publications of the Society of a more general nature but related to printed wiring. There are the standards and other technical publications on electrical insulating materials, metal cleaning, and electrodeposited metallic coatings which may be located by referring to the *Index to ASTM Standards* and the *List of ASTM Publications*. Both the index and the list are free on request.

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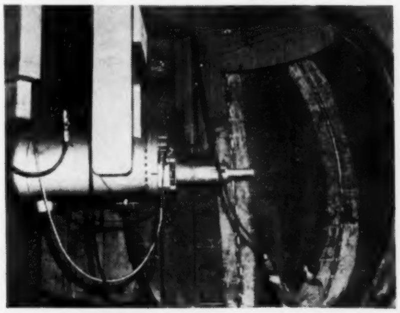

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Radiograph showing mild steel seam of reactor before cladding.

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BOOKSHELF

Members who wish to be considered for reviewing books are invited to send in their names and subjects in which they are interested. Due to customs and mailing considerations, requests from the United States only can be considered. Copies of these books are not available through ASTM; all inquiries concerning them should be addressed to the publisher.

Metals Handbook, 8th Edition, Vol. 1

Properties and Selection of Metals, American Society for Metals, Novelty, Ohio (1961); 1300 pp.; Illus.; $30.00.

Adapted from publisher's description.

BECAUSE IT is the first volume of a projected series, the new ASM Metals Handbook is a far more specialized book than its predecessors. It deals exclusively with the selection and properties of metals, in a greatly expanded and more intensified coverage. When the remaining volumes are completed, the handbook series will cover all branches of metals engineering and metalworking.

A preponderant majority of the metals and alloys dealt with in this volume are covered by ASTM standards. A wealth of numerical information in the form of charts, graphs, and tables make the data easily accessible. The new volume bears a more intimate relation to engineering and production practices; this is apparent from the large number of specific examples and comparisons that have been used to illustrate a variety of selection problems.

The text of the current volume is generally lucid and reflects careful editing. Representing the work of more than 1300 contributors, it contains 98 principal articles, 14 short summary articles, 456 compilations of data on specific alloys, 2806 definitions, 35 reference tables, and a 64-page index.

Some insight into the general content of the book can be gained from a review of a few of its major sections. For example a new 286-page section on carbon and low-alloy steels contains six major articles on selection for specific engineering properties (yield strength, fatigue resistance, notch toughness, etc.); eight additional articles on selection for processing and economy (sample titles: "Selection of Low-Carbon Steel Sheet for Deep Drawing," "Selection of Steel for Economy in Machining"); and 12 articles on product forms and their properties. Reflecting the work of 19 ASM committees (and a total of 287 contributors), this section alone contains more than 1900 illustrations and 351 tables.

Other sections of the book are equally comprehensive in covering the cast metals and alloys and stainless steels and heat-resisting alloys. A section on tool materials deals with tool wear, tool life, and tool economy in production. Coordinated with these extensive production data are 71 selection tables which recommend tool materials (including nonmetallics) for 2300 applications of specific tools.

Separate sections of the book are devoted to each of the eight principal nonferrous metals. More pages than ever before are assigned to magnetic, electrical, and other special-purpose metals, precious metals, and—a subject of rapidly expanding interest—the properties of pure metals. An edge index has been provided so that principal sections of the book can be located quickly from marginal marks on the flyleaf just inside the front cover.

Handbook of Thermophysical Properties of Solid Materials

Edited by Alexander Goldsmith, T. E. Waterman, and H. J. Hirschhorn; The Macmillan Co., New York, N. Y. (1961); 4300 pp. in 5 vols.; $90.00 (prepublication price $75 until Aug. 14, 1961).

Adapted from publisher's description

THREE YEARS of effort by the staff of the Armour Research Foundation under contract with the U. S. Air Force have resulted in this 5-volume handbook. Results of research on thermophysical properties published over a 17-year period are tabulated here. In all, the work has taken 20 years to complete.

Prepared originally for the exclusive use of Air Force contractors in aircraft, missile, space, and nuclear science fields, this handbook is now available for general use. It contains published data on twelve thermophysical properties of solid materials including elements, alloys, ceramics, cermets, polymers, and composite materials. These data were obtained from such sources as *Chemical Abstracts*, *Metallurgical Abstracts*, *Nuclear Science Abstracts*, and *Armed Services Technical Information Agency*.

Of the twelve properties covered in the handbook, five (density, melting point, latent heat of fusion, latent heat of vaporization, latent heat of sublimation) are grouped together for convenience on a single data sheet. The seven other properties (specific heat, thermal conductivity, thermal diffusivity, emissivity-reflectivity, linear thermal expansion, vapor pressure, and electrical resistivity) are evaluated on separate data sheets and plotted on separate graphs as functions of temperature.

(*Continued on next page*)

Rare Metals Handbook, 2nd Edition

Edited by Clifford A. Hampel; Reinhold Publishing Co., New York, N. Y. (1961); 732 pp.; Illus.; $20.00

Adapted from publisher's description

COMPILED BY 44 experts, this handbook presents the full range of currently available data on 55 of the less common metals. Information on cesium, chromium, plutonium, rubidium, scandium, and yttrium has been added in this edition. Separate chapters on columbium and tantalum have been prepared. With few exceptions the chapters contain greatly enhanced presentations of information due not only to the additional data developed in the past several years, but also to the release of large amounts of hitherto classified information.

A new format facilitates speedy reference to such aspects as occurrence, production statistics, economics, derivation, alloys, and applications. Properties and comparisons between metals are shown in convenient tabular form wherever possible, and complete reference lists close every chapter.

Introduction to Ceramics

By W. D. Kingery; John Wiley & Sons, Inc., New York, N. Y. (1960); 759 pp.; $15.00

Reviewed by S. F. Etris, ASTM Staff

A STUDENT IN the ceramics field is soon faced with a paucity of texts on this subject. Although the industry ranks seventh in dollar volume in the United States, and the demand for ceramics engineers is high, there are few ceramics schools and these have a modest level of enrollment. It is this latter factor that discourages potential authors.

Professor Kingery, a member of the ASTM Committee on Ceramic Whitewares for some years, has based his book on the precept that ceramics are an important class of materials, as the list of ASTM "C" committees will attest. An associate professor of ceramics, Massachusetts Institute of Technology, and recipient of the Ross Coffin Purdy Award (1954), and the first John Jeppson Medal (1958), the author was schooled in MIT's theoretical approach to ceramics and his book reflects this. The graduate student will recognize information that he formerly had to obtain from a number of different texts; having the essentials all in one text will make Kingery's book attractive to every ceramics student's pocketbook.

Covering the current status of ceramics—its raw materials, the atomic, molecular, and crystallographic aspects, the electrical and other physical properties of its products, as well as the forming processes—the book has a broad appeal for ceramics schools. The fact that some of the examples are somewhat out of date will detract little from this welcome contribution to the ceramics literature.

(Continued on page 498)

BOOKSHELF

(*Continued from page 497*)

Heat Treatment and Properties of Iron and Steel

T. G. Digges and S. J. Rosenberg; National Bureau of Standards Monograph 18 (October, 1960); 40 pp.; 35 cents in U.S.A., all others 45 cents (remittances mandatory in U. S. exchange); (Order from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.)

Adapted from publisher's description.

THE NATIONAL BUREAU of Standards receives many requests for general information concerning the heat treatment of iron and steel and for explanations of such processes. This monograph has been prepared to answer such inquiries and to give, in simplified form, a working knowledge of the basic theoretical and practical principles involved in the heat treatment of iron and steel. The effects of various treatments on the structures and mechanical properties of these materials are described. Some theoretical aspects and technical details are discussed only briefly or omitted entirely for better understanding of the general subject.

The monograph also contains a complete listing of all current structural, tool, and stainless steels, and their recommended heat treatments.

X-Ray Microscopy

By V. E. Cosslett and W. C. Nixon; Cambridge University Press, New York, N. Y. (1961); 406 pp.; Illus.; $15.00.

Reviewed by H. C. Stumpf, Aluminum Company of America, New Kensington, Pa.

THIS BOOK is a valuable addition to a distinguished series, the Cambridge Monographs on Physics. The authors are particularly capable of writing on this subject, having achieved renown for development of the X-ray point projection microscope.

This book supplies a comprehensive account of all methods for X-ray microscopy, including contact microradiography, point projection microscopy, and X-ray reflection microscopy. The coverage is even extended to the techniques of X-ray absorption microanalysis and X-ray emission microanalysis. The first eight chapters of the book are devoted to the principles of the various methods, and the text includes many references to a very thorough biblography of source material. Chapters 9 through 11 describe the practical aspects of the use of the methods, including specimen preparation and the construction and operation of the instruments. Chapters at the end of the book give examples from application, a discussion of microdiffraction, and descriptions of new methods such as the use of the image intensifier. Appended are tables of absorption coefficients and emission wave lengths.

This book contains a large amount of reliable information, emphasizing basic principles, but at times is rather heavy going. One minor criticism might be that the authors are somewhat too meticulous with cross references. Thus the reader may be hindered by three or four references to other sections in the course of a paragraph. However, the material is thoroughly and authoritatively covered, which makes this a valuable source book on X-ray microscopy.

Techniques of Nondestructive Testing

Edited by C. A. Hogarth and J. Blitz; Butterworth & Co., Ltd., Washington, D. C. (1960); 224 pp.; $7.50.

Adapted from publisher's description.

LATE IN 1959 a series of lectures on "The Techniques of Nondestructive Testing" was given at Brunel College, England, and attended by a large number of people from industry. Those attending suggested that the material from the lectures, given mainly by specialists in their particular subjects, could form the basis for a book which would be of use to inspectors and other concerned with the application of nondestructive testing techniques.

Most of the chapters are self-contained accounts of the theory and practice of electrical, magnetic, mechanical, and visual testing techniques. Other chapters devoted to ultrasonic, radiographic, and thermal comparator methods are supported by thorough introductions to their scientific background. A final contribution outlines the manner in which many of the techniques are in current use within the Aeronautical Inspection Directorate Laboratories, Harefield, England.

Nondestructive Testing

Warren J. McGonnagle; McGraw-Hill Book Co., Inc., New York, N. Y. (1961); 458 pp.: $15.00.

Adapted from publisher's description

THE PHYSICAL principles, techniques, advantages, and limitations of the various methods of nondestructive testing are covered comprehensively in this newly published volume. Based on applied physics, the treatment in the book stresses nondestructive testing as a science and outlines the *what, why, how, when,* and *where* of this rapidly developing technology. The author points out that this type of testing is concerned not only with the detection and location of flaws in material, but that its methods and techniques are used to measure physical properties or nonuniformities in the physical properties of specific materials.

Physical principles which underlie a particular test method form the basis for each of the book's chapters, and special techniques for solving a variety of practical problems are included. Among the major testing procedures treated in detail in this integrated volume are visual testing, pressure and leak testing, liquid penetrant inspection,

thermal methods, X-ray and gamma radiography, ultrasonics, dynamic testing, magnetic and electric techniques, and eddy current methods.

Nondestructive test work in the growing field of atomic energy is emphasized. Another feature of the book is the number of detailed illustrations and tables which highlight actual test procedures. Other topics presented in this guide include a complete chapter on thickness measurements and a section devoted to such specialized techniques as spot tests, sulfur printing, spectrochemical analysis, spark testing, activation analysis, residual stress, and many others.

Semiconductor Abstracts, Vol. VI (1958)

Edited by J. J. Balloff and C. S. Peet; John Wiley & Sons, Inc., New York, N. Y.; 528 pp.; $14.00.

Reviewed by F. Y. Speight, ASTM Staff.

THIS USEFUL volume was compiled by staff members of Battelle Memorial Inst. as part of a continuing project under the auspices of the Electrochemical Society. The work on Volume VI covering the literature on semiconductors published during 1958 was partly supported by the Air Force Office of Scientific Research.

In comparison with previous volumes, this volume has a more complete subject index and the first abstract on a given subject is longer, with subsequent ones shorter. Also, when papers are presented orally and later published, both references appear with the same abstract. All these innovations make the book more convenient for the user. Altogether there are 1933 abstracts included in Volume VI.

OTS REPORTS

These reports, recently made available to the public, can be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Order by number.

Deflection Characteristics of a 20-Foot-Diameter Laminated Wood Ring Subjected to Compressive Loading Along a Diameter, PB 171165, 75 cents.

USSR Literature on Air Pollution and Related Occupational Diseases. Volume 1, 60-21049, $3.50; Volume 2, 60-21188, $4; Volume 3, 60-21475, $4; and Volume 4, 60-21913, $4.

Limits of Allowable Concentrations of Atmospheric Pollutants, 59-21173. Book 1, $2.75; Book 2, 59-21174, $3; and Book 3, 59-21175, $3.

Sanitary Protection of Atmospheric Air; Purification of Industrial Discharge Gases from Suspended Substances, 1955, 59-21092, $3.

Continuous Filament Ceramic Fibers, *PB 171 061*, $2.25.

Handbook for the Foundry Worker—Shape Casting of Aluminum and Magnesium Alloys (USSR), *60-21972 Part 1*, $3.50; *60-21973 Part 2*, $3.

Potential Applications of Radioisotopes to the Mining, Preparation, Transportation, Storage, Handling and Use of Coal, *NYO 2859*, $3.

Study of the Industrial Potential of Radioisotopic Methods in the Textile Industry, *NYO 2640*, 50 cents.

Study of the Industrial Potential of Radioisotopic Methods in the Synthetic Detergent and Soap Industry, *TID-6088*, $1.25.

Molded Composite for Boat Hulls, *PB 171 168*, $1.25.

The Effect of Individual Lamination Thickness on the Strength of Curved and Straight White Oak Beams Containing Cross Grain, *PB 171 174*, $1.25.

Strength of Curved and Straight Dense Douglas Fir Laminates as Affected by Individual Lamination Thickness, *PB 171 176*, $1.25.

Effect of Board Width on Bending Radii of White Oak and Douglas Fir, *PB 171 173*, 50 cents.

Bending Radii of Tanalith-Treated Southern Yellow Pine as Affected by Knot Size, *PB 171 170*, 50 cents.

Effect of Lamination Thickness on Shrinkage and Swelling of White Oak Laminates, *PB 171 175*, 75 cents.

Effect of Board Thickness on Bending Radii of EKKI Boards, *PB 171 172*, 50 cents.

Bending Radii of Dense, Flat-Sawn Douglas Fir as Affected by Slope of Grain and Knots, *PB 171 169*, 75 cents.

(*Continued on page 508*)

MATERIALS AND TESTING TOPICS

This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

FOR THE LABORATORY

Vibration Fatigue—Production of Model 150-HLA-T, a new precision vibration fatigue testing machine designed for pilot, spot, or production-line testing of electronic, electrical, optical, and mechanical equipment has been announced.
All American Tool & Mfg. Co. **3773**

Pore Determinations—Quick, easy, and accurate pore structure evaluations, increasingly important in the fields of plastics, food, and medicinal products, sintered metals, ceramics, and structural materials are now readily obtainable using the Aminco-Winslow porosimeter. Based on the mercury - intrusion principle whereby samples are immersed in mercury and subjected to varying degrees of pressure, the porosimeter permits plotting pressure and volumetric readings on semilog graph paper from which pore diameter and penetration data can be directly extracted.
American Instrument Co., Inc. **3774**

Noise Generating System—Based on the siren-type noise generator, these units are designed to produce high-intensity sound for research and proof testing involving acoustic fatigue on structures and components. Model 825 can generate more than 164 db sound pressure level in a 1 sq ft test section (2500 w of acoustic power), and Model 820 can generate 168 db sound pressure level in a 1 sq ft test section (10,000 w of acoustic power).
American Measurement & Control, Inc. **3775**

Residual Magnetism—A new pocket instrument that instantly measures the degree of residual magnetism in steel tools, parts, and structures is offered. Known as the Annis pocket magnetometer, it readily indicates low residual magnetism levels required for good "fuzz-free" parts cleaning.
R. B. Annis Co. **3776**

Relative Humidity Chamber—Facility in meeting specific requirements of MIL-202B is an advantage offered by Blue M's new Model VP-206A vapor-temp controlled relative humidity chamber. This equipment is designed specifically, and guaranteed to meet MIL-202B, method 106A, steps 1 to 6.
Blue M Electric Co. **3777**

Electronic Control—A highly sensitive, fast-responding electronic relay that will switch up to 15 amp with a 1.8 microamp or less control signal has been announced. The switch, designed to operate solenoids, heaters, regulators, instruments, contact meters, etc., has relay contacts that will handle a maximum of 15 amp at 115 v, 60 cycle ac (noninductive load) when triggered by anything from a short circuit, or zero ohms, to 10 megohms resistance.
Central Scientific Co. **3778**

Ultrasonic Flaw Detector—The Metalloradar, a unique ultrasonic flaw detector which operates without the liquid coupling required in all flaw detectors commonly in use today, has been introduced. The ultrasonically vibrating crystal in the device is intimately coupled to the object being tested, through the medium of a newly-developed synthetic membrane that fits tightly over the transducer.
Circo Corp. **3779**

Temperature Cycling—The development of a new temperature chamber, Model 1060F, has been announced. This portable table top model is designed to give a complete cycle between −100 and +500 F in less than 12 min. Control accuracy is $\pm\frac{1}{2}$ F.
Delta Design, Inc. **3780**

Accelerometer—The new Endevco Model 2227 microminiature accelerometer weighs only 3.1 g, is $\frac{1}{2}$ in. high, and includes an integral No. 6–32 stud. The design provides mechanical isolation from noise-producing cable stress. Voltage sensitivity with 180 pf external capacity is 5.0 peak mv per peak *g* nominal; resonance frequency is 30 kcps nominal; cross-axis sensitivity is 5 per cent maximum; temperature range is −65 to +350 F with 15 per cent or less nominal sensitivity deviation throughout this temperature range.
Endevco Corp. **3781**

Optical Instruments—For precise and efficient inspection of survey-type optical instruments such as theodolites, transits, levels, and jig transits, a universal short-range test fixture has been developed.
Engis Equipment Co. **3782**

Recorder—A rugged and compact recorder having fully transistorized circuitry, positive drive action, a built-in voltmeter, and a direct-reading range dial has been ntroduced. This recorder provides a stable, noise-free magnetic flowmeter a-c potentiometer.
Fischer & Porter Co. **3783**

Thermometer—A precision differential thermistor thermometer capable of measuring temperatures to 0.001 C is now available. Designed for use in measuring temperature fluctuations in colorimetry, change-of-state experiments, research reaction studies, cryoscopy, and chemical and medical research, these new precision thermometers open new areas of temperature measurement and calibration.
Fiske Associates, Inc. **3784**

Strain-Gage Logger—New Model 179 strain-gage logger, a 200-channel instru-

(*Continued on page 502*)

FOR THE LABORATORY

(Continued from page 500)

ment contained in one standard 19-in. relay rack, has been announced. The Model 179 is a medium-speed, absolute millivolt instrument which scans 200 channels of strain data at a rate of 5 channels per sec.
Gilmore Industries, Inc. **3785**

Brightness Pyrometer—The PYRO-650, an optical brightness pyrometer that makes possible continuous recording and controlling of high temperatures in the range from 1200 to over 7000 F, has been introduced.
Instrument Development Laboratories, Inc. **3786**

Dipole Moments—The Dipolemeter DM 01 is a precision measuring instrument designed for the evaluation of the molecular electrical dipole moment of liquids by accurate measurement of the dielectric constant. It further permits exact determinations of the dielectric constant of liquids, pastes, and solids for nondestructive quality control, purity test, dielectric analyses, chemical investigations, etc., because of its extremely sensitive measuring range. Interchangeable cells and micrometer electrodes are available for the various media and substances to be analyzed.
Kahl Scientific Instrument Co. **3787**

Oscillator—A new 1-cps to 100-kc stable-amplitude ultra-low distortion oscillator featuring 0.01 per cent amplitude stability and 0.01 per cent distortion is now available. Designated Model 446, this new oscillator is designed for critical applications such as refined meter calibration and distortion measurements.
Krohn-Hite Corp. **3788**

Vibration Machine—A new, compact, low-cost reaction-type vibration machine designed and constructed for use in quality control, environmental testing, and general engineering and research laboratories has been announced. The Type RVP-16-50 has a 50-lb test load capacity and a 15-*g* maximum acceleration rating. Operating with total excursions up to 0.100 in. maximum, the machine will meet a wide range of military specifications and commercial vibration testing requirements.
L.A.B. Corp. **3789**

Temperature-Humidity Chamber—The addition of a 4-cu ft upright chamber to the line of temperature-humidity test cabinets has been announced. This high-performance unit has a temperature range of 0 to 200 F with a control tolerance of ±2 F and a humidity range of 20 to 95 per cent RH within ±5 per cent.
Labline, Inc. **3790**

Furnace—L & L's Dyna-Trol furnaces have been designed and constructed for special use in research laboratories. Dyna-Trol is a small, compact furnace which heats up to 2000 F in 1 hr; 2300 F in 1½ hr. A constant level of temperature ranging from 300 to 2300 F can be maintained by means of input controllers. These can be set at from 7 to 100 per cent of input.
L & L Manufacturing Co. **3791**

Furnaces—Originally designed to meet U. S. Air Force specifications, this series of seven furnaces is used for hardening, annealing, drawing, and preheating. The 5055 Series furnaces are of box-type construction with chamber temperatures of 2000 and 2300 F.
Lucifer Furnaces, Inc. **3792**

Magnetic Particle Testing—A complete new family of materials for the wet method of visible and fluorescent magnetic particle testing is being introduced. The new materials, called concentrates, are all in powder form. They have a measurable increase in fluorescent brillance from 70 to 600 per cent, closely controlled particle size range, less foaming, and more corrosion protection.
Magnaflux Corp. **3793**

Distillation Rack—A new concept in function and style for a laboratory's distillation rack has been developed. The Corner-Scope distillation rack presents unusual features not ordinarily found in this type of equipment. The rack permits two independent complex setups to be carried on simultaneously without interference of personnel or apparatus. Both vertical and horizontal rods are adjustable. An infinite number of rod arrangements is thus possible for any desired positioning of clamps and apparatus on the rods.
Metalab Equipment Co. **3794**

Potentiometer—A new linear-motion potentiometer with a stroke of 12 in. has been introduced. This potentiometer has a wire-bound element with high resolution and a standard linearity of 0.05 per cent—closer linearity can be supplied on special order.
New England Instrument Co. **3795**

Magnetic Tester—A much lighter and smaller version of the Picker mobile 3000-amp magnetic particle unit has been developed for industrial inspection of a wide variety of metal products. The unit, called the Mobile Ferroscope, operates on ac or half-wave dc and is especially effective in detecting surface and subsurface flaws in parts too large for inspection on stationary wet horizontal units.
Picker X-Ray Corp. **3796**

Chromatograph—Baseline stability with exceedingly low drift, dual detection including catalytic combustion and thermal conductivity, wide attenuation with 1 to 125 four-position selectivity, and high sensitivity detecting 5 ppm hydrogen in any gas are four outstanding features of the new Chronofrac, Model VP-1, recently introduced.
Precision Scientific Co. **3797**

Analyzer—A new differential Auto-Analyzer for continuous chemical analysis, with automatic blank or interference compensation, that can detect trace materials down to parts per billion with an accuracy of 1 per cent has been announced.
Technicon Controls, Inc. **3798**

Freezing Point—Freezing-point standards, furnished with National Bureau of Standards certified freezing-point samples, are being introduced. The apparatus provides an accurate and convenient means of reproducing primary and secondary points

in the International Temperature Scale for the calibration of temperature-sensing devices. Temptron's freezing-point standards are designed to use the methods specified in Section 3.1 of NBS Bulletin 590, "Methods of Testing Thermocouples and Thermocouple Materials."
Temptron, Inc. **3799**

Indicators—The new, small Thermo electronic self-balancing indicators provide accurate, automatic, rapid indication of a wide variety of industrial processes. They can be used with hundreds of sensing elements connected through any type of multi-point switches or connector panels. The indicating controllers also provide two- (off-on) or three-position control of processes.
Thermo Electric Co., Inc. **3800**

Soil Tester—An improved system for determining per cent moisture and density of soil by nuclear methods has been announced. This equipment, while adaptable to a wide range of uses, finds its largest present demand in compaction control and study of soil moisture and density conditions prior to highway and dam construction. It also finds wide usage in moisture studies relative to water conservation, agricultural, and irrigation control projects.
TESTlab Corp. **3801**

NEW LITERATURE

Ultrasonic Cleaner—A bulletin describing the new self-tuning, transistorized 20-kc line of ultrasonic cleaners is available. The literature elaborates upon the 20-kc cleaner's advantages over older vacuum tube systems. Advantages described are: lighter weight and compactness; choice of selectable power levels; and automatic compensation for load and liquid levels.
Acoustica Associates, Inc. **6433**

Funnels—A new catalog sheet detailing a new separable Buechner table-type funnel of either branch or linear-type polyethylene has been published. The literature shows how the simple, two-piece funnel fits together to make a positive, leak-proof seal, yet quickly and easily separates for cleaning or sterilizing.
The American Agile Corp. **6434**

Chemical Standards—The introduction of the Standardettes, chemical standards which permit laboratory technicians to accurately standardize titrating solutions to four-figure accuracy in a matter of minutes is announced. A 6-page illustrated folder has been released, giving detailed descriptions, prices, packaging, and applications of Standardettes.
Chemical Service Laboratories **6435**

Gold-Cobalt Thermocouples—A new four-page *Technical Bulletin CG 357* comparing gold-cobalt with copper thermocouples is offered. A chart shows comparisons of sensitivities over temperature spans encompassing some normal boiling points. Some possible thermocouple configurations are illustrated along with a

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NEW LITERATURE

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typical rake installation, and specifications and available options are listed.
Cryogenics, Inc. **6436**

Resistance Wire—Improved properties of KARMA fine resistance wire for precision resistors and potentiometers are described in a new *Technical Information Bulletin No. 102*. With a new standard temperature coefficient of resistance of ± 5 ppm in fine sizes, the improved KARMA wire also shows greater stability of resistance.
Driver-Harris Co. **6437**

Shadograph—A new 8-page 2-color illustrated catalog on Shadograph scales and weighing equipment for industrial, laboratory, and commercial applications is now available. Shadograph scales are predetermined weight scales with a 1 : 1 ratio even-balance lever to provide high sensitivity.
The Exact Weight Scale Co. **6438**

Potentiometer—A new catalog of the standard high-precision, single-turn, linear and nonlinear potentiometers has been issued. General information on each model is accompanied by complete electrical and mechanical specifications, including a temperature rating curve.
Instruments for Industry, Inc. **6439**

Resistance Standards—A new 4-page *Data Sheet EB2(1)* describing precise d-c electrical standards is now available. The electrical standards described include: the Thomas-type 1-ohm standard with a measured value given to 1 ppm, NBS-type resistance standards, Reichsanstalt-type resistance standards, secondary-standard d-c resistors, a mercury-cup stand, shunts for large currents, and secondary a-c resistors.
Leeds & Northrup Co. **6440**

Oscillographs—A revised *Product Digest No. 160* with pictures and a brief description of a complete product line of wet-process and direct-readout oscillographs, galvanometers, bridge balance units, and galvanometer amplifiers is available.
Midwestern Instruments, Inc. **6441**

X-Ray Microscope—A new 8-page folder titled "Isolation of Selected Elements With An X-ray Projection Microscope," reprint of an article by a Pomona College physicist, is available. The author covers: basic idea, value of absorption coefficient ratio, analyzing pictures by electronics, analyzing pictures photographically, preliminary results, instrument requirements, and conclusions.
Philips Electronic Instruments **6442**

Catalog—*Catalog 109* is now available, the newest and most up-to-date catalog for scientific laboratories. Here is an encyclopedia of scientific instruments, apparatus, and chemicals, with nearly 1500 pages of comprehensive listings for scientific men working in a professional capacity.
E. H. Sargent & Co. **6443**

Concrete Testing Machines—A new 6-page illustrated brochure on a wide variety of concrete testing machines has been issued. The machines illustrated and described are of a type that can be used either in the field for on-the-job testing or in permanent laboratory installations. All equipment is made in accordance with the accuracy and design requirements of ASTM and AASHO.
Soiltest, Inc. **6444**

Testing Machines—A new *Brochure No. G-361* describes a complete line of Brinell hardness testing machines, penetrascopes, ductility testers, tensile and compression testing machines, transverse testers, hydrostatic and pneumatic testing machines, proving rings and calibration presses, and special testing machines.
Steel City Testing Machines, Inc. **6445**

Noise Generators—A new, 4-page color bulletin on the Stentor series of wide-band noise generators is available. The illustrated bulletin includes specifications of the Stentor 203, 204, and 205 noise generators, which are designed for acoustical qualification tests, sonic fatigue tests, transmission-loss studies, and material evaluation.
Tenney Engineering, Inc. **6446**

LABORATORIES

Fabric Research Laboratories, Inc., Dedham, Mass.—An extensive laboratory for the experimental spinning of synthetic fibers has been established, according to an announcement by Walter J. Hamburger, director. The new facility, which has been more than two years in planning and construction, is capable of both melt and solvent (dry) spinning which includes nylon, polypropylene, polyethylene, polyester, polyvinyl alcohol, acetate, and acrylic-fiber spinning methods.

Rototest Laboratories, Inc., Lynwood, Calif.—Rototest offers a unique service, providing 6000 amp at 28 v dc, regulated, suitable for testing of high-power switches, relays, circuit breakers, etc.

MATERIALS

Urethane Foam—A new line of rigid urethane foam sheets, designed to meet the growing demand for high-efficiency, space-saving insulation, has been introduced. In addition to the standard urethane foam, Barrett has introduced a flame-retardant coated version designed to minimize fire hazards during construction.
Allied Chemical Corp., Barrett Div., New York, N. Y.

Gallium Compounds—Gallium arsenide in single and polycrystal forms for use in tunnel diodes, varactor diodes, microwave diodes, and transistors is now available. The compound is available in resistivity ranges of 0.0X to 0.00X ohm-cm for p-type devices and 0.X to 0.00X ohm-cm for n-type devices. It has a carrier concentration of 4×10^{16} to 5×10^{19} carriers per cu cm and mobility up to and better than 4500 sq cm volt-sec.
Alloys Unlimited Chemicals, Inc., Long Island City, N. Y.

Tool Steel—A new steel has been developed which can be heat treated to tensile strengths in excess of 350,000 psi. Even at this high strength level, the material retains ductility and impact strength. The alloy was designed for tools and dies that require resistance to extreme shock. As an ultra-high strength steel, the new alloy is recommended for critically stressed components where maximum strength is required with the least sacrifice in toughness.

The Carpenter Steel Co., Reading, Pa.

Plating on Molybdenum—The availability of nickel plating directly on molybdenum sheets, particularly for use as a semiconductor structural material is announced. For many types of semiconductors, the presence of an undercoating on the molybdenum supports is objectionable, and the new process eliminates this intermediate layer. The nickel may be applied to one or both sides of the molybdenum and, if one side alone is plated, the exposed side is electropolished for cleansing of surface impurities.

Chromium Corporation of America, New York, N. Y.

Hafnium Silicides—The high hardness, relative ductility, thermal stability, and low coefficient of friction exhibited by these materials suggest strongly their application as a hard facing material for application to valve or bearing surfaces subjected to high loads at elevated temperatures. Some physical properties of these materials are: density, 10 to 13 g per cu cm at 30 C; electrical resistivity, 100 to 300 μohm at 30 C; melting point, 2200 to 2500 C; bend before rupture, 10 to 20 deg; coefficient of friction (clean), 0.2 to 0.5 at 30 C; thermal conductivity, less than 0.05 cal cm per sec deg Cent; and thermal coefficient of expansion approx. 8 $\times 10^{-6}$ per deg Cent.

Electronic Materials Corp., Santa Monica, Calif.

Silicone Catalog—A new 8-page, 2-color catalog describing the complete line of General Electric silicones and their uses is now available. Designated CDS-129C, the catalog is liberally illustrated with photos and contains data pertaining to the various silicone products, including a complete selector guide for silicone rubber.

General Electric Co., Waterford, N. Y.

Special Coatings—Four page folder describes line of 18 special coatings for all types of industry, designed for one or more of the following uses: product protection, improvement of appearance, mold or die release, and dry lubrication. Coatings described fall in four general chemical categories: wax emulsions, resin emulsions, solvent-base waxes, and self-polishing solvent-base waxes and resins. Description includes data on methods of application, coverage, drying time, and characteristic uses on such materials as metals, leather, paper, plastic, rubber, wood, etc.

S. C. Johnson & Son, Inc., Racine, Wis.

Asbestos-Cement Sheets—A new line of colored asbestos-cement structural sheets is described in a full-color 4-page folder.

Keasbey & Mattison Co., Ambler, Pa.

Carbon-Graphite Materials—An 8 page illustrated engineering guide on carbon-graphite materials for mechanical applications is available. Grade recommendations are presented for seals and sliding surfaces for a wide range of liquids and gases at operating temperatures up to 500 F, above 500 F, and in the cryogenic range. Detailed discussions are included on this material's high elastic modulus, total impermeability, maintained flatness, resistance to chemical attack, thermal conductivity, and low friction and wear.

National Carbon Co., New York, N. Y.

Copper-Clad Laminated Plastics—Revised Synthane standards for copper-clad laminated plastics conforming to the latest issue of Military Specification MIL-P-13949B (plastic sheet, laminated, copper clad for printed wiring) have been issued in an up-to-date brochure.

Synthane Corp., Oaks, Pa.

Titanium—"Titanium for Missiles," a 14-page study summarizing the six major application areas for titanium in missile construction, has been published. The publication, showing in full-color the nation's entire arsenal of missiles and space vehicles now under design or construction, also includes brief discussion of the four titanium alloys of greatest significance to the missile builder.

Titanium Metals Corporation of America, New York, N. Y.

NEW MEMBERS

The following 71 members were elected from April 7, 1961 to May 5, 1961 making the total membership 10,487 . . . Welcome to ASTM. Names are arranged alphabetically, company members first, then individuals. Your ASTM Year Book shows the areas covered by the respective Districts.

Chicago District

Coleman Instruments, Inc., John J. J. Staunton, director of research, Maywood, Ill.
Buckstaff, John, Jr., president, Buckstaff Co., Oshkosh, Wis.
Glaberson, Louis, design engineer, Hotpoint, Division of General Electric Co., Chicago, Ill.
Kinsman, Shepard, national sales manager, Coulter Electronics, Inc., Chicago, Ill.
MacKinney, Paul M., president, Concrete Controls Corp., Wheaton, Ill.
Pandelis, Charles R., manager of metallurgy, Combustion Engineering, Inc., East Chicago, Ind.

Cleveland District

Coleman, W. E., specification engineer, tubular products, Republic Steel Corp., Youngstown, Ohio.
Farrar, M. B., manager of sales, Kemet Co., Cleveland, Ohio.
Wagener, J. S., manager, research and development, Kemet Co., Cleveland, Ohio.

Detroit District

Abram, Wilbert L., chief engineer, Precision Spring Corp., Detroit, Mich.
Asvestis, Efstathios H., laboratories supervisor, Dow Chemical International S. A., Midland, Mich.
Brignone, Cesare, laboratory supervisor, Dow Chemical International S. A., Midland, Mich.
Pate, Laurence H., vice-president, Pate & Hirn, Inc., Detroit, Mich.
Vild, Donald J., Glass Specifications Dept., Libbey-Owens-Ford Glass Co., Toledo, Ohio.
Wood, B. J., vice-president, Harley, Ellington, Cowin & Stirton, Detroit, Mich.

Mississippi Valley District

Weeks, Gaylord D., vice-president, Wright-Weeks, Inc., Springfield, Mo.
Wright, H. Garrett, president, Wright-Weeks, Inc., Springfield, Mo.

New England District

Cutcliffe, J. Lloyd, instructor, Massachusetts Institute of Technology, Cambridge, Mass. [A]*
Cutts, Howard H., technical director, Union Paste Co., Hyde Park, Mass.
Dhosi, Joseph M., metallurgist, New England Materials Laboratory, Medford, Mass.
King, Edward J., assistant chief engineer, The Billings & Spencer Co., Hartford, Conn.

New York District

Stamford Chemical Industries, Inc., Edwin B. Michaels, research director, Stamford, Conn.
Ayres, George H., materials engineer, M. F. Hickey Co., Brooklyn, N. Y.
Cottle, H. N., chief engineer, MB Electronics, A Division of Textron Electronics, Inc., New Haven, Conn.
Field, James W., technical director, Packaging Inst., Inc., New York, N. Y. [A]
Simoons, Daniel, lubricants technologist, Tidewater Oil Co., New York, N. Y.
Turner, Sid W., metallurgical engineer, Lead Industries Assn., New York, N. Y.
Warren, John A., John A. Warren Associates, Baldwin, N. Y.

Northern California District

Degenkolb, Henry J., vice-president, Gould & Degenkolb, Consulting Engineers, San Francisco, Calif.
Tompkins, Lewis C., president, Industrial Kanugen Corp., Emeryville, Calif.

Northwest District

Arestad, O. T., chief chemist, laboratory, Harvey Aluminum Corporation of Oregon, The Dalles, Ore.

Ohio Valley District

Fink, Robert K., instructor, civil and mechanical engineering, Case Institute of Technology, Cleveland, Ohio. [A]
McKeehan, Ernest R., program engineer (ATP), General Electric Co., Cincinnati, Ohio. [A]
Rhoden, Ivan E., director of research, Link-Belt Co., Indianapolis, Ind.

Philadelphia District

Herasimchuk, Michael V., metallurgical engineer, Bethlehem Steel Co., Inc., Bethlehem, Pa.
Moyer, Clyde T., Jr., district manager, The Budd Co., Instrument Div., Phoenixville, Pa.

Pittsburgh District

Alexander, Jack L., manager, analytical laboratory, Koppers Co., Inc., Tar Products Div., Verona, Pa.
Gribble, Frank E., assistant chief metallurgist, Edgar Thomson Works, U. S. Steel Corp., Braddock, Pa.

Rocky Mountain District

Mallard, Manley T., chief chemist and mill production manager, R. E. Darling Co., Tucson, Ariz.
U. S. Army Electronic Proving Ground, director, Technical Library, Fort Huachuca, Ariz.

Southeast District

Space Science Services, Inc., Roger D. Langley, vice-president, Orlando, Fla.
Nelson, Donald H., vice-president and director of laboratories, Metallurgical Inspection and Testing Co., Fort Lauderdale, Fla.
Sherman, Robert H., vice - president, Claussen-Lawrence Construction Co., Augusta, Ga.

Southern California District

Libbert, Barbara Ann, research engineer, Narmco Research and Development, Division of Narmco Industries, Inc., San Diego, Calif.

Southwest District

Bostic, Thomas G., general manager, Bostic Concrete Co., Inc., Lafayette, La.
Harris, John J., senior engineer, Magnolia Pipe Line Co., Dallas, Tex.
Malloy, Harold C., engineer, Texaco, Inc., Houston, Tex.
Matson, R. F., superintendent, research and development, Freeport Sulphur Co., Port Nickel, La.

Washington, D.C., District

Head, Edward J., general manager, Aggregate Dept., Clinchfield Coal Co., Dante, Va.
Owens, Grover C., Jr., Technical Dept., Pacific Mills, Raeford, N. C.
Pfeiffer, Frederick W., Jr., junior mechanical engineer, Emerson Research Laboratory, Silver Spring, Md. [A]
Sallberg, John R., highway research engineer, Bureau of Public Roads, Washington, D. C.

* [A] denotes Associate Member.

(*Continued on page 508*)

NEW MEMBERS

(*Continued from page 507*)

Williams, Stuart, highway supervisory research engineer, Bureau of Public Roads, Washington, D. C.

Western New York–Ontario

Allsopp, W. E., sales manager, Industrial Div., Williams Gold Refining Co., Inc., Buffalo, N. Y.

Ingersoll, Clyde E., director of research and engineering, Williams Gold Refining Co., Inc., Buffalo, N. Y.

Outside Established Districts

Bruesch, Lawrence D., bridge engineer, U. S. Forest Service, Department of Engineering, Missoula, Mont.

Hanley, M. J., specifications writer, Honolulu, Hawaii.

Honolulu, City and County of, Building Dept., Tsutomu Izumi, building superintendent, Honolulu, Hawaii.

Johnson, John, supervising architect (general), U. S. Army District Engineers, Omaha, Nebr.

Other Than U. S. Possessions

Nueva Montana de Quijano, Eduardo de Quijano, managing director, Santander, Spain.

Bond, Wilfred James, executive director, The Limmer & Trinidad Lake Asphalt Co., Ltd., London, England.

Girault, Pablo, consulting engineer, Girault y Cia, Mexico D. F., Mexico. [A]

Holmgren, E. F., manager, Materials Testing Laboratories, Ltd., Edmonton, Alta., Canada.

Jugoslovenski Zavod za Standardizaciju (Yugoslav Institution for Standardization), S. Vitorovic, director, Belgrade, Yugoslavia.

Kazmierski, Marian M., general manager, Smelter Plant, Chile Exploration Co., Chuquicamata, Chile.

Ma, Omar N. L., in charge of Quality Control Dept., Nanyang Cotton Mill, Ltd., Kwun Tong, Kowloon, Hong Kong, Free China.

Martineu, Henri Michel, materials and paving engineer, J. A. Jones Construction Co., Teheran, Iran.

Ogata, Yukio, chief of technical section, Toyo Continental Carbon, Ltd., Chuo-ku, Tokyo, Japan.

Paternoster, Luigi, surveyor, S.A.U.T.I. Co., Ahwaz, Iran.

Pichardo, Enrique Partida, electrical engineer, Crouse Hinds Domex S. A. de C. V., Vallejo, Mexico D. F., Mexico. [A]

Weisz, Michel, engineer, C. E. A. Service Technologie, Saclay S & O, France.

OTS REPORTS

(*Continued from page 499*)

Simplified Practice Recommendation P16-53 on Softwood Lumber, 10 cents.

Uniform Grades of Laminated Hardwood Flooring Blocks, *CS 233-60*, 10 cents.

Toxicity of Chemicals to Marine Borers, *PB 161 909*, $2.75.

Simplified Practice Recommendation Acoustical Material, *R262-60*, 10 cents.

Investigation of the High-Speed Impact Behavior of Fibrous Materials—Part 1 Design and Apparatus, *PB 171 311*, $1.

Simulated Combined Vibration, Sustained Acceleration and Extreme Temperature Environments, *PB 171 134*, 50 cents.

Response of Plates to Moving Shocks, *PB 171 302*, $1.

Notch Sensitivity of Refractory Metals, *PB 171 198*, $2.50.

CALENDAR

July 5–8—**National Society of Professional Engineers,** Annual Meeting, Olympic Hotel, Seattle, Wash.

July 27–Aug. 1—**International Symposium on Macromolecular Chemistry,** Queen Elizabeth Hotel, Montreal, Canada

July 30–Aug. 4—**American Crystallographic Association,** University of Colorado, Boulder, Colo.

Aug. 3–5—**The Chemical Institute of Canada,** Annual National Conference, Queen Elizabeth Hotel, Montreal, Canada

Aug. 5–14—**International Committee on Cellulose Analysis** (Executive Committee Meeting Aug. 5; General Meeting Aug. 14), Queen Elizabeth Hotel, Montreal, P. Q.

Aug. 6–12—**International Congress of Pure and Applied Chemistry,** 18th International Congress (Wood Chemistry Symposium), Queen Elizabeth Hotel, Montreal, P. Q.

Aug. 13–18—**International Symposium on Micro - Chemical Techniques,** Conference Center, The Pennsylvania State University, University Park, Pa.

Aug. 14–17—**Society of Automotive Engineers,** National West Coast Meeting, Sheraton Hotel, Portland, Ore.

Aug. 23–26—**Electron Microscope Society of America,** 19th Annual Meeting, Pittsburgh Hilton Hotel, Pittsburgh, Pa.

Aug. 28–Sept. 1—**International Heat Transfer Conference,** University of Colorado, Boulder, Colo.

Aug. 30–Sept. 1—**American Institute of Mining, Metallurgical, and Petroleum Engineers,** Conference on Metallurgy of Semiconductor Material, Ambassador Hotel, Los Angeles, Calif.

Sept. 3–8—**American Chemical Society,** National Meeting, Chicago, Ill.

Sept. 14–15—**American Institute of Electrical Engineers and American Society of Mechanical Engineers,** Engineering Management Conference, Hotel Roosevelt, New York, N. Y.

Sept. 18–22—**Instrument Society of America,** Conference and Exhibit, New York, N. Y.

Sept. 19–21—**Technical Association of the Pulp and Paper Industry,** Fourth International Mechanical Pulping Conference, Edgewater Beach Hotel, Chicago, Ill.

Sept. 24–26—**Steel Founders' Society of America,** Fall Meeting, The Homestead, Hot Springs, Va.

Sept. 24–27—**American Public Works Association,** Public Works Congress and Equipment Show, Hotel Leamington and Auditorium, Minneapolis, Minn.

Sept. 24–27—**American Institute of Chemical Engineers,** National Meeting, Lake Placid Club, Lake Placid, N. Y.

Sept. 24–29—**Illuminating Engineering Society,** National Technical Conference, Chase Park Plaza Hotel, St. Louis, Mo.

Sept. 25–28—**American Welding Society,** National Fall Meeting, Hotel Adolphus, Dallas, Tex.

Sept. 25–28—**Association of Iron and Steel Engineers,** Convention, Penn Sheraton Hotel, Pittsburgh, Pa.

NEWS OF MEMBERS

At the Annual Business Meeting of the American Foundrymen's Society new officers were elected and honors were presented. **John A. Wagner,** president, Wagner Castings Co., Decatur, Ill., was elected vice-president; **Harvey E. Henderson,** technical director, Research Dept., Lynchburg Foundry Co., Lynchburg, Va., received an Award of Scientific Merit "for valuable contributions to metallurgical research in the casting of gray and ductile iron"; and **Alexander D. Barczak,** operations vice-president, Superior Foundry, Inc., Cleveland, Ohio, received an Award of Scientific Merit "for outstanding and inspirational services to AFS, its Chapters, and the ferrous foundry industry, for inspirational encouragement of young men to foundry careers, and for constant willingness to help the other fellow."

ASTM members number among the newly elected officers of the American Hot Dip Galvanizers Assn. **T. R. Gregory,** president, Thomas Gregory Galvanizing Works, Maspeth, N. Y., was elected first vice-president; **Cooper Hawthorne,** vice-president and general manager, Metal Services, Inc., Port Neches, Tex., was elected second vice-president; **Charles E. Perry** was re-elected to the post of secretary-treasurer, and **John R. Daesen** will serve as technical director.

Newly elected officers of the American Oil Chemists' Society include **A. E. MacGee,** manager, Industrial Div., Skelly Oil Co., Kansas City, Mo., vice-president and **R. C. Stillman,** technical service analytical standards, Procter & Gamble Co., Cincinnati, Ohio, member-at-large.

The American Society of Mechanical Engineers has announced the promotion of some of its members to the grade of Fellow. These include **Henry E. Aldrich,** manager, American Boiler Manufacturers Assn., Newark, N. J; **Eugene H. MacNiece,** technical consultant, Permacel-LePages, Johnson & Johnson, New Brunswick, N. J.; and **Carl O. Myers,** secretary-treasurer, National Board of Boiler and Pressure Vessel Inspectors, Columbus, Ohio.

New officers and directors announced by the American Society of Lubrication Engineers include **L. B. Sargent, Jr.,** Aluminum Company of America, Pittsburgh, Pa., vice-president at large; **R. K. Gould,** Texaco Inc., Beacon, N. Y., New York regional vice-president; **A. E. Cichelli,** Bethlehem Steel Corp., Bethlehem, Pa., re-elected secretary; and **H. T. Peeples,** Timken Roller Bearing Co., Canton, Ohio, will continue to serve as a director. **Robert Q. Sharpe,** Socony Mobil Oil Co., New York, N. Y., was given the Wilbur Deutsch Award for the best practical paper of the year, "Reducing Leakage from Hydraulic Systems."

The American Welding Society at its Annual Meeting elected new officers and presented awards to its members. **E. C. Miller,** inspection engineer, Oak Ridge National Laboratory, Union Carbide Nuclear Co., Oak Ridge, Tenn.; and **A. N. Kugler,** chief welding engineer, Air Reduction Sales Co., New York, N. Y., were elected directors-at-large. **R. D. Thomas, Jr.,** president, Arcos Corp., Philadelphia, Pa., received the Past-President's Certificate; **R. W. Emerson,** assistant to the president, and general technical coordinator, Pittsburgh Pipe and Equipment Co., Pittsburgh, Pa, received the District Meritorious Certificate Award; and **W. H. Munse,** University of Illinois, Urbana, Ill., was presented with an Adams Memorial Membership.

G. H. LeFevre, U. S. Smelting Refining and Mining Co., New York, N. Y., and **J. L. Kimberley** were re-elected treasurer, and vice-president and secretary, respectively, of the American Zinc Institute, Inc.

Kenneth G. Compton of Bell Telephone Laboratories, Inc., Murray Hill, N. J., received the 1960 Speller Award, and **H. R. Copson,** head, Corrosion Section, The International Nickel Co., Inc., Bayonne, N. J., received the 1960 Whitney Award at the 17th Annual National Conference of the

(*Continued on page 510*)

NEWS OF MEMBERS

(*Continued from page 509*)

Association of Corrosion Engineers in Buffalo, N. Y.

P. H. Bates, 1620 Seventh St., North, St. Petersburg, Fla., is recovering nicely from a recent operation. Mr. Bates, who served as president of ASTM in 1944–1945, is retired from the National Bureau of Standards, where he was chief, Clay and Silicate Products Div

David R. Brobst retired recently from the Bell Telephone Laboratories, Inc., Murray Hill, N. J. Mr. Brobst represented his firm on Committee B-1 on Wires for Electrical Conductors and its subcommittees. He also was a member of ASA C7, Sectional Committee on Bare Electrical Conductors.

Wallace R. Brode, former science adviser to the Department of State, was elected president of the Society of Sigma Xi at its recent convention. He will serve until 1963.

John D. Campbell, project engineer in charge of environmental test laboratory, Philco Corp., Palo Alto, Calif., has been elected vice-president, publications, Institute of Environmental Sciences.

Bonner S. Coffman is now associate professor of civil engineering at Ohio State University's Transportation Engineering Center, Columbus, Ohio. Formerly he was consulting engineer, soils, Washington, D. C.

Lionel A. Cox is now vice-president, research and development, Personal Products Corp., Milltown, N. J. Formerly he was director of research, Johnson & Johnson, Ltd., Montreal, P. Q., Canada.

Louis W. Currier, formerly with the U. S. Geological Survey, Washington, D. C., is now a consultant in engineering geology, construction stones, and industrial minerals resources, Washington, D. C.

Conant Dodge, chief design engineer, Weyerhaeuser Timber Co., Tacoma, Wash., has been appointed manager of the Engineering Department.

Jay E. Evans, formerly general manager, Law Engineering Testing Co., Birmingham, Ala., is now plant manager, Concrete Products Div., American-Marietta Co., Birmingham, Ala.

Ralph A. Evans is now physicist, Research Triangle Inst., Durham, N. C. Previously he was director, research laboratory, Link-Belt Co., Indianapolis, Ind.

A. N. Gray, formerly consultant, Edgewood, Md., is now consulting engineer, Superior Cable Corp., Hickory, N. C

In the special Orange Show section of the Colton, Calif., *Courier*, there is reference to ASTM Honorary Member **Wilson C. Hanna,** who after 50 years of service with the California Portland Cement Co. retired recently and is a consultant. Mr. Hanna has been chairman since 1947 of the Orange Show Exhibit Committee, Colton Chamber of Commerce.

W. L. Havekotte is now plant metallurgist, Union Electric Steel Corp., Pittsburgh, Pa. Formerly he was chief project engineer, A. M. Byers Co., Ambridge, Pa.

F. H. Hedger has been named associate director of quality control, Charles Pfizer and Co., Inc., Brooklyn, N. Y. He had been director, Analytical Dept.

R. M. Kennedy, chief, Metals and Ceramics Laboratory, Materials Central, U. S. Department of the Air Force, Wright Air Development Div., Wright-Patterson Air Force Base, Ohio, retired recently. At the time of his retirement, Mr. Kennedy represented the Air Force on Committees B-6 on Die Cast Metals and Alloys, and A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys. In earlier years he represented the Air Force on Committees B-7 on Light Metals and Alloys, and B-5 on Copper and Copper Alloys.

Roland P. Koehring, chief metallurgist, Delco Moraine Div., General Motors Corp., Dayton, Ohio, has been named a Powder Metallurgy Pioneer by the Metal Powder Industries Federation as a tribute to his 40 years of pioneering effort in the powder metallurgy industry. Mr. Koehring represented his company in Society membership for many years and also on Committee B-9 on Metal Powders and Metal Powder Products, of which he was a founder member. He also was a member of the Ohio District Council. In recognition of his outstanding contributions to the Society he was presented with an Award of Merit in 1956.

The many friends and associates of ASTM Past-President **R. T. Kropf** have been pleased to note his election as president of Belding Heminway Company, Inc., New York, N. Y. Mr. Kropf was vice-president and director of research. In ASTM, Mr. Kropf has been extremely active in Committee D-13 on Textile Materials, serving as an officer and as a member of many subcommittees. This year he is completing a notable service of nine years on the Board of Directors, currently serving as chairman of the Finance Committee. Mr. Kropf has been not only greatly concerned with the Society's activities and administration, but has always shown intense interest in the operations and welfare of the Headquarters Staff.

Sherwood V. Marlow is now test engineer, Stevens Institute of Technology, Davidson Laboratory, Hoboken, N. J. He had been soils inspector, E. Lionel Pavlo, Consulting Engineers, New York, N. Y.

J. B. Morey, mechanical engineer, The International Nickel Co., Inc., Cincinnati,

Ohio, retired recently. Mr. Morey held membership in ASTM since 1944.

Henry B. Oatley, consultant, Great Neck, N. Y., was the guest of honor at a meeting on April 20 of the Long Island Section of The American Society of Mechanical Engineers when he was presented with a gold membership pin signifying completion of 50 years of membership. Dr. Oatley is an honorary member of ASTM, having served on Committees A-1 on Steel, of which he is honorary member, and A-3 on Cast Iron. He retired in 1950 from the Superheater Co., New York, N. Y., where he served as chief engineer, vice-president, and consulting engineer.

A. R. Presto, formerly chemist, Kimberly-Stevens Corp., is now research chemist, Texon, Inc., S. Hadley Falls, Mass.

Stanley L. Proud, formerly engineer of foundations, Pacific Architects and Engineers, San Francisco, Calif., is now a highway engineer, International Cooperation Administration, Bandung, Indonesia. He is adviser to the Ministry of Public Works Highway Div., Bandung, Java.

George F. Quimby, consultant, Soft Fibre Manufacturers' Inst., Wilton, Conn., retired recently. Mr. Quimby joined ASTM in 1937, and since that time has been a member of Committee D-13 on Textile Materials.

Claude K. Rice, formerly coordinator, Refinery Technology Laboratory, Gulf Research and Development Co., Philadelphia, Pa., is now director of laboratories, Venezuela Gulf Refining Co., Barcelona, Anzoategui, Venezuela. Mr. Rice has been quite active in Committee D-19 on Water and recently received the Max Hecht Award for 1961 for outstanding work in the field of industrial water.

James M. Rice, director, road research, Natural Rubber Bureau, Washington, D. C., has been elected president of the Association of Asphalt Paving Technologists.

Stuart T. Ross, formerly manager, Physical Metallurgy Aeronutronic Div., Ford Motor Co., Newport Beach, Calif., has been named vice-president, research and engineering, Brooks & Perkins, Inc., Detroit, Mich.

Charles H. Scholer, professor of applied mechanics, Road Materials Laboratory, Kansas State University, Manhattan, Kansas, retired recently. Since joining the Society in 1919, Professor Scholer has been active in technical committee work. He served on Committees C-9 on Concrete and Concrete Aggregates and D-4 on Road and Paving Materials for 35 years each. He was a member of Committee C-1 on Cement for more than 25 years and was chairman of several subcommittees. Other ASTM technical activities include subcommittees of Committees E-1 on Methods of Testing, E-9 on Research, Joint Research Committee on Durability of Concrete, of which he was elected chairman, and ASA A37, Sectional Committee on Road and Paving Materials. In recognition of his long and faithful service he was presented with an ASTM Award of Merit in 1960. Professor Scholer will continue his membership in the Society.

O. Douglas Schumann is now with Aberfoyle Mfg. Co., New York, N. Y., as sales administrator. He had been marketing group manager, Fiber Dept., Air Reduction Chemical Co., New York, N. Y.

A. G. Scroggie, research manager, E. I. du Pont de Nemours and Co., Inc., Textile Fibers Dept., Technical Div., Chestnut Run, Wilmington, Del., retired recently. Dr. Scroggie has been a member of the Society for more than 30 years and has been active in technical committee work. His main interest was in Committee D-13 on Textile Materials, which he has served for 32 years. He was first vice-chairman of the committee for six years and chairman of several subcommittees. In 1956 he was presented with the Harold DeWitt Smith Award for achievement in the field of textile fiber utilization. Other ASTM activities include Committees D-12 on Soaps and Other Detergents, E-8 on Nomenclature and Definitions, E-11 on Quality Control of Materials, and D-23 on Cellulose and Cellulose Derivatives.

R. W. Simon was appointed vice-president, metallurgy, United States Steel Corp., Pittsburgh, Pa. Previously he was chief metallurgical engineer.

I. Melville Stein, president, Leeds & Northrup Co., Philadelphia, Pa., has been elected a section chairman of the Scientific Apparatus Makers Assn.

Harvey T. Stitt is now president, Stitt Construction Co., Denver, Colo. Previously he served in the same capacity for Denver Mud Jack Co., Denver, Colo.

Robert S. Strimel has been appointed assistant to the president, Tinius Olsen Testing Machine Co., Willow Grove, Pa.

John F. Thompson, honorary chairman of the board, The International Nickel Company of Canada Ltd., saw his distinguished career in mining and metallurgy climaxed in March with the start of production at Inco's new nickel facility located at the town of Thompson, in northern Manitoba. With a capacity of 75 million lb per year, the Thompson plant will be the Free World's second largest nickel producer. Dr. Thompson has been a Society member since 1907.

Emerson Venable, consulting chemist and engineer, Pittsburgh, Pa., is the new secretary of the Association of Consulting Chemists and Chemical Engineers, Inc.

Ernest A. Wass is now junior plant engineer, Beech-Nut Lifesavers, Inc., Canajoharie, N. Y. Formerly he was office manager, Valliere Drapery Studio, Rochester, N. Y.

Alfred C. Webber, ASTM director and vice-presidential nominee, formerly senior supervisor, Experimental Station, E. I. du Pont de Nemours and Co., Inc., Polychemicals Dept., Research Dept., Wilmington, Del., is now assistant to the laboratory director.

DEATHS

E. W. Campion, chairman, The Bonney-Floyd Co., Columbus, Ohio (March 1, 1961). Mr. Campion joined ASTM in 1934 as an individual member, but since 1936 he had represented his firm in Society membership and on Committees A-1 on Steel and A-10 on Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys. He also was a member of the Ohio Valley District Council.

Herbert A. Davis, a 40-year member of ASTM, and president, Washington Concrete Products Corp., Arlington, Va. (February 16, 1961).

Harry L. Fisher, Claremont, Calif. (recently). Dr. Fisher, prior to his retirement in 1956, taught at the School of Engineering, University of Southern California, Los Angeles, Calif. In recognition of his contributions to the work of Committee D-11 on Rubber and Rubber-Like Materials, he was elected an honorary member of this committee. In 1941 he delivered the Edgar Marburg Lecture on the subject "Natural and Synthetic Rubbers."

Ralph E. Hall, Rehoboth Beach, Del. (May 2, 1961). Before retiring in 1951, Dr. Hall had been a member of the board of directors and a consultant for Hall Laboratories, Inc., Hagan Bldg., Pittsburgh, Pa. He was an active member of Committee D-19 on Industrial Water for many years, having served as secretary from 1934 to 1950. He was a member of many of its subcommittees and was elected an honorary member of the Committee in 1950.

Earl F. Kelley, formerly chief, Division of Physical Research, Bureau of Public Roads, Washington, D. C. (April 20, 1961). The Society has lost a member who gave it strong technical and administrative support for many years. An authority in the field of road materials, Mr. Kelley was for 36 years with the Bureau of Public Roads. He wrote extensively and assisted ASTM in its development of technical papers and reports. He was active in the work of many technical committees, notably D-4 on Road and Paving Materials, of which committee he is an honorary member. He also served as chairman of Committee C-13 on Concrete Pipe. Some of his other long-time committee affiliations include A-1 on Steel, A-3 on Cast Iron, and E-1 on Methods of Testing. He supported the Washington District activities consistently and was a past chairman of the district.

Charles E. Paul, St. Petersburg, Fla. (May 2, 1961). Professor Paul moved to Florida shortly after his retirement from the Illinois Institute of Technology, Chicago, Ill., in 1942. He was a member of ASTM for more than 50 years, and participated in the activities of Committee D-7 on Wood.

E. S. Petruniak, resident manager, Pittsburgh Testing Laboratory, Syracuse, N. Y. (recently). Mr. Petruniak joined the Society in 1959.

Lyle R. Sheppard, senior engineer, technical service, Shell Pipe Line Corp., Houston, Tex. (December 12, 1960). Mr. Sheppard had been a member of the Society for only a short time.

J. C. Smack, staff assistant to general manager, Curtiss-Wright Corp., Princeton Div., Princeton, N. J. (April, 1961). Mr. Smack joined ASTM in 1949 as an individual member and more recently represented his company in Society membership. His activities included Committee E-7 on Nondestructive Testing, Subcommittee 3 of E-1 on Methods of Testing, and the Philadelphia District Council.

F. W. Smither, Mobile, Ala. (March 8, 1961). Mr. Smither had been a member of ASTM since 1912 and was elected to honorary membership in 1951. He was active in many technical committees, his main interest being in Committees D-12 on Soaps and Other Detergents and D-1 on Paint. Mr. Smither was the recipient of the first Committee D-12 Award in 1958. Other committee activities included C-7 on Lime, D-19 on Industrial Water, D-17 on Naval Stores, several subcommittees of E-1 on Methods of Testing, and the Joint Committee on Analysis of Soaps and Synthetic Detergents. Mr. Smither was a chemist with the National Bureau of Standards in Washington, D. C.

D. W. Sudell, superintendent, Cities Service Oil Co., Petty Island Plant, Camden, N. J. (December 17, 1960). He had been a member of the Society since 1954.

GOVERNMENT STANDARDS CHANGES

THE FEDERAL Supply Service of the General Services Administration is charged with the responsibility for establishing specifications to be used by the Federal Government for Procurement of materials and supplies. The GSA issues an annual Index of Initiation of Federal Specifications Projects, and monthly supplements.

The following are taken from Supplement 1 for March, 1961.

INITIATIONS

Title	Type of Action	Symbol or Number	FSC Class	Assigned Agency and Preparing Activity
Rubber, Sampling and Testing	Chg. Not. 1	Fed. Std. 601	...	GSA-FSS
Conduit and Fittings, Plastic	New	L-C-00740	...	GSA-FSS
Insulation, Thermal, Flexible Unicellular (Sheet and Pipe Covering)	New	HH-I-00573	5640	GSA-FSS
Lubricating Oil, Light (General Purpose)	Rev.	VV-L-820b VV-L-00820a	9150	GSA-FSS
Matting, Rubber and Plastic	Rev.	ZZ-M-71a	...	NAVY-Docks
Nickel-Copper-Alloy (Monel and R-Monel), Bar, Plate, Rod, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections	Am. 1	QQ-N-281a	9535	AFSSC
Paper, Kraft, Untreated, Wrapping	Am. 1	UU-P-268e	8135	GSA-FSS
Pipe, Copper, Seamless, Standard	Rev.	WW-P-377b	4710	USAF
Pipe, Pressure, Steel, Cement Mortar Lining and Reinforced Cement Mortar Coating	New	SS-P-00385	5630	INT-BR
Steel, Alloy, Sheet and Strip, Hot-Rolled	New	QQ-S-627b	9515	ARMY-ORD
Tester, Hardness Durometer	New	GGG-T-190a GGG-T-00190	6635	ARMY-ORD
Wire Rope and Strand	Int. Am. 1	RR-W-410a	4010	NAVY-Ships

PROMULGATIONS

Title	Type of Action	Symbol or Number
Tolerances for Aluminum Alloy and Magnesium Alloy Wrought Products	Rev.	Fed. Std. 245a
Tolerances for Copper and Copper-Base Alloy Mill Products	New	Fed. Std. 146
Ammonia, Technical (Superseding O-A-445)	Rev.	O-A-445a
Battery Water (Superseding O-B-0041(Navy-Ships) & O-W-41a)	New	O-B-41a
Cable, Power, Electrical, (Rubber-Insulated, Building-Type) and Wire, Electrical, (Rubber-Insulated, Building-Type)	Am. 2	J-C-103b
Cloth, Cotton, Muslin, Bleached and Unbleached (Superseding CCC-C-00446(GSA-FSS) & CCC-M-911)	New	CCC-C-446a
Paper, Kraft, Untreated, Wrapping	Am. 1	UU-P-268e
Paper, Shredded, Waxed	Rev.	PPP-P-150a
Perchloroethylene (Tetrachloroethylene), Technical Grade	Am. 1	O-P-191a
Pigment, Zinc Oxide, Dry and Paste-in-Oil (Superseding TT-P-00463(GSA-FSS) & TT-Z-301a)	New	TT-P-463a
Pipe-Fittings, Brass or Bronze, (Screwed), 125-and 250-lb (Superseding WW-P-460)	Rev.	WW-P-460
Primer Coating, Synthetic, Rust-Inhibiting, Lacquer-Resisting (Superseding TT-P-664)	Rev.	TT-P-664a
Scouring Powder (Superseding P-S-311)	Rev.	P-S-311a
Spikes and Nails, Common Cut; Spikes, Gutter and Round, Wire; and Spikes, Barge and Boat, Wrought	Am. 1	FF-S-606
Steel, Alloy, Sheet and Strip, Hot-Rolled (Superseding QQ-S-00627a(Army-Ord))	Rev.	QQ-S-627b

CANCELLATIONS

Title	Symbol or Number	Reason for Cancellation
Drums, Steel, Type 5 (for inflammable or Poisonous Liquids)	RR-D-726	Superseded by PPP-D-729
Drums, Steel, Type 6C (for Inflammable Solids and Oxidizing Materials)	RR-D-741	Canceled
Glass Cleaner, Powder	P-G-411	Superseded by P-S-320a
Plastic Sheet, Sensitized	L-P-00518 (Navy-Aer)	Superseded by L-F-340
Potassium Metabisulfite, etc.	O-P-560	
Potassium Permanganate, etc.	O-P-562	
Potassium Persulfate, etc.	O-P-565	
Pyrocatechol, Photographic, etc.	O-P-951	
Pyrogallic Acid, Photographic etc.	O-P-961	
Sodium Acetate, Anhydrous, etc.	O-S-573	
Sodium Borate, Decahydrate, Photographic	O-S-661b	
Sodium Bisulfite, Photographic etc.	O-S-579	Superseded by O-C-275
Sodium Carbonate, etc.	O-S-580b	
Sodium Carbonate, Monohydrate, etc.	O-S-581d	
Sodium Chloride, Photographic, etc.	O-S-586	
Sodium Hydroxide (Caustic Soda) Photographic	O-S-603b	
Sodium Metaborate, Octohydrate, Photographic	O-S-629b	
Sodium Sulfite, Anhydrous, Photographic	O-S-606c	
Sodium Sulfate, Photographic etc.	O-S-609	
Sodium Thiosulfate, Photographic	O-S-616c	
Water, Battery	O-W-41a	Superseded by O-B-41a

(*Continued on page 514*)

(Continued from page 513)

SPECIFICATIONS AND STANDARDS APPROVED FOR PRINTING

Title	Type of Action	Symbol or Number
Glossary of Packaging Terms	Rev.	Fed. Std. 75a
Aluminum Alloy Bars, Rods, and Shapes, Extruded, 7075	Am. 1	QQ-A-277a
Aluminum Alloy, Plate and Sheet 7075	Am. 1	QQ-A-283a
Aluminum Alloy Plate and Sheet 5052	Am. 2	QQ-A-318c
Amyl Alcohol, Secondary	Rev.	TT-A-516b
Borers, Cork	Canc.	GG-B-591
Borer Set, Cork	New	NNN-B-600
Box, Wood, Cleated, Veneer, Paper Overlaid	New	PPP-B-576
Brass, Leaded and Nonleaded, Flat Products (Plate, Bar, Sheet, and Strip)	Rev.	QQ-B-613b
Brass, Leaded and Nonleaded, Rod, Shapes, Forgings, and Flat Products with Finished Edges (Bar, Flat Wire, and Strip)	Rev.	QQ-B-626b
Brass, Naval (Flat Products) Plate, Bar, Sheet, and Strip	New	QQ-B-639
Brass, Naval; Rod, Wire, Shapes, Forgings, and Flat Products With Finished Edges (Bar, Flat Wire, and Strip)	New	QQ-B-637
Cellulose Acetate Plastic Sheets	Canc.	L-C-169
Chloroform, Technical	Rev.	O-C-291a
Cleaning Methods and Pretreatment of Ferrous Surfaces for Organic Coatings	New	TT-C-490
Cloth, Jute (or Kenaf), Burlap	Rev.	CCC-C-467a
Cloth, Tracing, Sensitized	Rev.	DDD-C-471c
Enamel, Semi-Gloss, Rust-Inhibiting	Am. 1	TT-E-485d
Fasteners, Slide, Interlocking	Rev.	V-F-106a
Flux, Brazing, Silver Alloy, Low-Melting-Point	Rev.	O-F-499a
Inhibitors, Pickling (for Use with Sulfuric Acid)	Am. 1	O-I-501a
Insulating Oil, Electrical (for Transformers, Switches, and Circuit Breakers)	Am. 2	VV-I-530
Isopropyl Acetate (for Use in Organic Coatings)	Rev.	TT-I-721b
Lead Sheet	Rev.	QQ-L-201d
Leather Dressing, Mildew-Preventive	Rev.	O-L-164b
Muslin, Bleached	Canc.	CCC-M-911
Naval Brass, Plate, Rolled Bar, Sheet and Strip	Canc.	QQ-N-30
Naval Brass, Rods, Bars, Wire, Shapes and Forgings and Flat Products with Finished Edges	Canc.	QQ-N-35
Oil, Pine	Canc.	LLL-O-358
Paper, Bond and Writing, White and Colored	Am. 1	UU-P-121j
Paper, Mimeograph	Am. 1	UU-P-388i
Perchloroethylene (Tetrachloroethylene), Technical Grade	Am. 1	O-P-191a
Pigment, Toluidine-Red-Toner, Dry	New	TT-P-445
Pigment, Zinc Oxide, Leaded (Dry and Paste-in-Oil)	New	TT-P-462a
Pine Oil	New	LLL-P-400a
Plastic Sheet and Film, Cellulose Acetate	New	L-P-504
Psychrometers	New	GG-P-725
Remover, Water Emulsion Type Floor Wax	New	P-R-201b

Roofing and Shingles, Asphalt-Prepared, Mineral-Surfaced	Canc.	SS-R-521
Roofing, Asphalt and Asbestos-Prepared, Mineral-Surfaces	Canc.	SS-R-511
Roofing, Felt, Roll, Asphalt-Prepared, Mineral-Surfaces	New	SS-R-630
Sodium Bicarbonate, Technical	Rev.	O-S-576c
Sodium Metasilicate, Technical	Rev.	O-S-604b
Steel Plate, Carbon	Rev.	QQ-S-635a
Tag Board, Jute	Am. 1	UU-T-75a
Toluidine-Red-Toner, Dry (Paint Pigment)	Canc.	TT-T-562
Tube, Steel, (Carbon, Mechanical, Seamless and Welded)	Rev.	QQ-T-830a
Wire, Fabric, Steel, Welded (for Reinforced Concrete)	New	RR-W-375
Wire, Steel, Corrosion-Resisting	Rev.	QQ-W-423a
Zinc Oxide, Dry and Paste-in-Oil	Canc.	TT-Z-301a
Zinc Oxide, Leaded (Dry and Paste-in-Oil)	Canc.	TT-Z-321a

The following are taken from the annual Index dated March 1, 1961.

NITIATIONS

Title	Type of Action	Symbol or Number	FSC Class	Assigned Agency and Preparing Activity
Specifications:				
Aluminum Alloy Forgings, Heat Treated	Am. 1	QQ-A-367e	9530	NAVY-WEP
Aluminum Alloy Plate and Sheet, 5052	Am. 1	QQ-A-318c	9535	GSA-FSS
Aluminum Alloy Rod and Wire, for Rivets and Cold Heading	Am. 1	QQ-A-430	9525	NAVY-WEP
Artificial Leather, Cloth, Coated, Vinyl Resin (Upholstery)	Rev.	CCC-A-700c	8305	ARMY-QMC
Box and Plastic Liner (for Liquids)	New	PPP-B-00569	8135	COM-BDSA
Carpets and Rugs, Velvet Plain and Twisted and Uncut Pile	Rev.	DDD-C-61d	8305	ARMY-QMC
Cloth, Coated (Rubber and Plastic Sheeting (Rolls) for Hospital Use	Rev.	ZZ-C-450a	8305	ARMY-QMC
Granules, Reflectorized	Am. 1	TT-G-00490	8010	NAVY-WEP
Packaging, Packing, and Marking of Textiles Fabrics (Woolens, Worsteds Cottons, Silks and Synthetics)	Rev.	PPP-P-51b	8305	ARMY-QMC
	Int. Am. 2	PPP-P-51a		

INDEX TO ADVERTISERS

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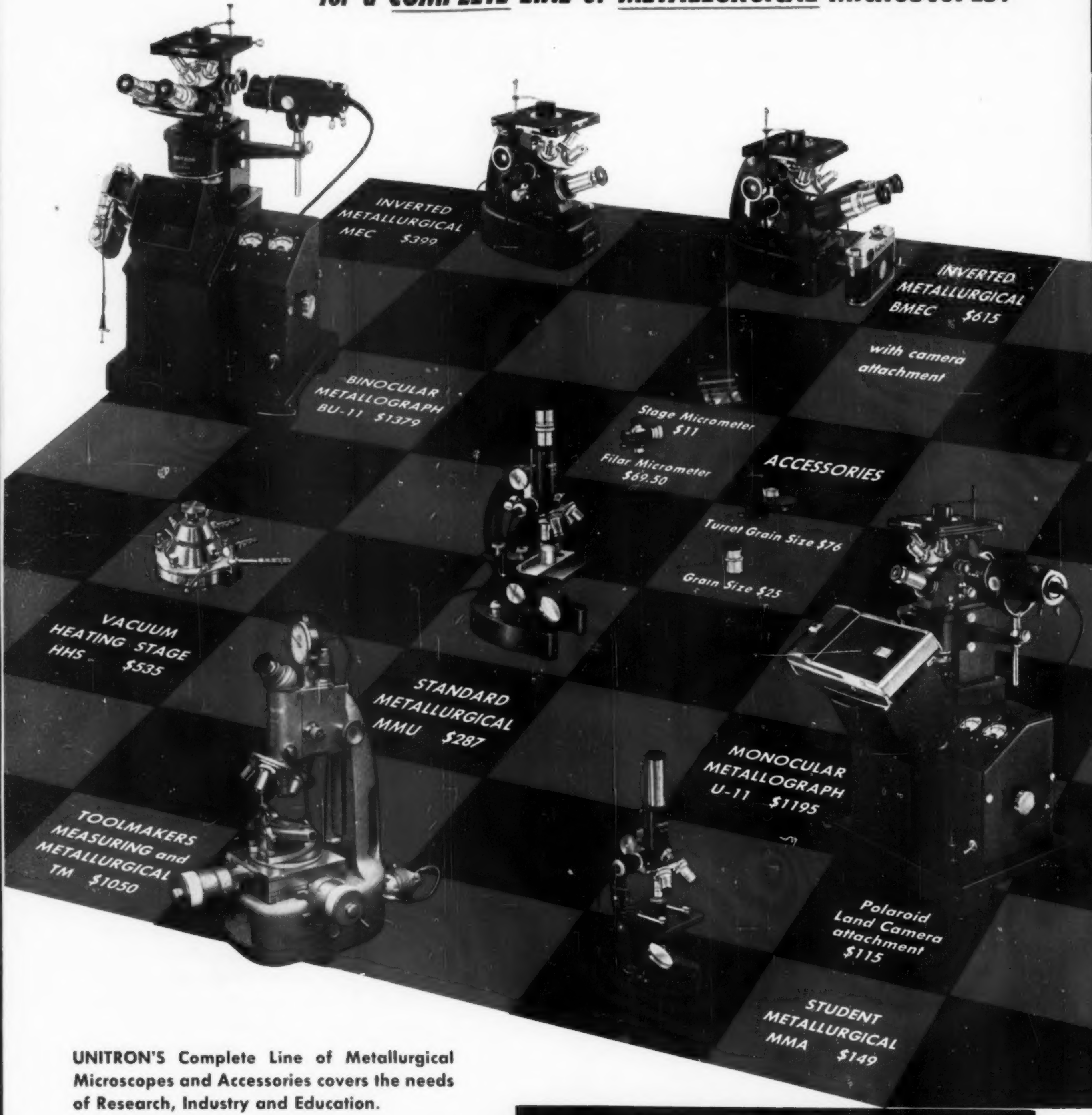

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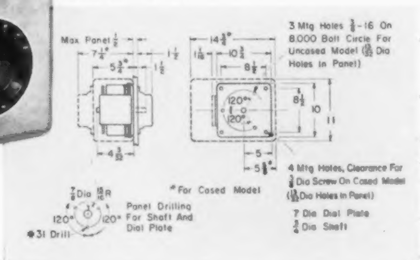

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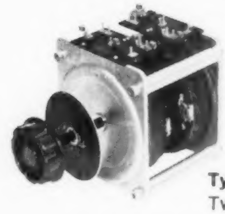
Type	Input Voltage	KVA	Voltage Range	Rated Current	Maximum Current	Voltage Range	Rated Current	Price
W30	120	4.32	0 to 120	30	36	0 to 140	30	$75.00
W30M*	120	3.84	0 to 120	28	32	0 to 140	28	97.00
W30H	240	3.74	0 to 240	12	15.6	0 to 280	12	75.00
	120	—	—	—	—	0 to 280	6	
W30HM*	240	3.74	0 to 240	12	15.6	0 to 280	12	97.00
	120	—	—	—	—	0 to 280	6	

No-Load Loss: 35 watts at 60 cps with rated input voltage.

GANGED MODELS



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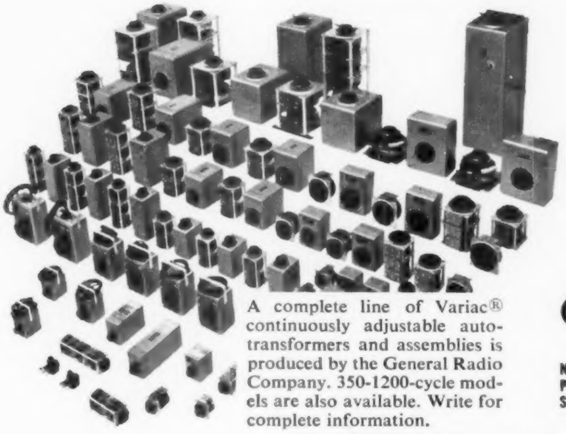
	Series	240	8.6	0 to 280	30.0	36.0	
W30G2M*	Parallel	120	7.7	0 to 140	56.0	64.0	190.00
	Series	240	7.7	0 to 280	28.0	32.0	
W30G3	Parallel	120	13.0	0 to 140	90.0	108.0	240.00
	3-Phase Wye	240	15.0	0 to 240	30.0	36.0	
W30G3M*	Parallel	120	11.5	0 to 140	84.0	96.0	275.00
	3-Phase Wye	240	13.3	0 to 240	28.0	32.0	
W30HG2	Parallel	240	7.5	0 to 280	24.0	31.2	160.00
	3-Phase, Open-Delta	240	6.48	0 to 280	12.0	15.6	
W30HG2M*	Parallel	240	7.5	0 to 280	24.0	31.2	190.00
	3-Phase, Open-Delta	240	6.48	0 to 280	12.0	15.6	
W30HG3	3-Phase Wye	480	13.0	0 to 480	12.0	15.6	240.00
W30HG3M*	3-Phase Wye	480	13.0	0 to 480	12.0	15.6	275.00

*Cased Model



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